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MILITARY MAP READING AND SKETCHING

INCLUDING CONTOURING

By MAJOR C. O. SHERRILL

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Google

Military Map Reading and Sketching

Including

CONTOURING

Return to
Civil Engr. Dept.
STANFORD UNIV.

BY

MAJOR C. O. SHERRILL

Corps of Engineers, U. S. Army

LATE INSTRUCTOR IN ENGINEERING AT THE ARMY SERVICE SCHOOLS,
FORT LEAVENWORTH, KANSAS

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MILITARY MAP READING AND SKETCHING

INTRODUCTION

1. Every officer and noncommissioned officer must know how to read maps before he can intelligently begin the study of tactics. This means to read and understand everything on a map as readily as one reads a book. He must form in his mind a picture of the country which the map represents.

2. No man can become an excellent sketcher until he involuntarily sees on the map forms which correspond to the ground observed, nor can he be a proficient map reader or scout until to see a map is at once to picture to himself intuitively the ground from which the map is made. A conscientious study and application of the subjects treated herein will give the average military man the topographical knowledge and training of the eye essential to every soldier. It is to be remembered that the final end of the study of sketching and map reading is not alone to become proficient in these two subjects, but also to learn everything about the military features of the ground and their representations on maps as a basis for the accurate and prompt solution of all military problems.

3. Not every officer and noncommissioned officer has facility for making sketches and consequently there are some who cannot hope to become expert in this work, yet this fact should not deter anyone from the study of this subject, because the military knowledge thereby obtained will be of much value. However, facility in handling a pencil is of small importance in this work, as is witnessed by scores of poor draftsmen who have become good sketchers, able to show clearly and accurately the essential features of the area sketched; but the facility that is required for learning to represent ground forms clearly, is the facility for mastering the details of these forms. This knowledge of ground

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is absolutely essential in every military operation and officers deficient in it who would become great tacticians or strategists must learn by patient effort that which very few know intuitively. —the relation between the ground and its corresponding map.

4. More men have been sacrificed in battle for lack of this knowledge of maps than from any other one thing, for ignorance of maps has been only too common in all armies in the past. General Kuropatkin, who commanded the Russian forces in the Russo-Japanese War, says: "A Regimental Commander could not as a rule read a map himself, much less teach those under him how to do so. This was especially the case at the beginning of the war and had considerable influence on the conduct of operations, as regiments often arrived late at their rendezvous, or went to points where they were not wanted."

As soon as you can read maps you can then begin to study tactical problems and take part in war games (map maneuvers). The basic principles of military problems are few and simple. The application of these principles on all kinds of ground is hard. If you know the military possibilities of ground and maps, you will have a good start on the study of tactics.

The object of this book is to help you, not only to make a good sketch and to read any map you may get hold of, but to help you to train your "topographic eye" so that you may, with one look over a landscape, be able to size up its tactical possibilities.

5. Part I of this book, called *"Military Map Reading"* describes those maps useful for military work and explains how to use them.

Part II, called *"Military Sketching"* describes the rapid making of military maps by simple methods and with simple equipment. Both of these subjects are so closely related that the study of one is necessary for the understanding of the other.

6. Acknowledgment is made to the Chief of Engineers for permission to use material from the *Engineer's Field Manual,* and to Keuffel & Esser Co. for plates of instruments.

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PART I

CHAPTER I

Classes of Maps

7. Maps are representations to scale, usually on a plane, of portions of the earth's surface. They are of various kinds, depending on the use for which they are intended and may or may not represent heights as well as horizontal distances; for instance the ordinary county map shows only roads, boundaries, streams and dwellings. A topographical map shows the horizontal and vertical relations of points and objects on the ground represented, and in addition gives information as to the character of the surface.

8. Suppose an officer is sent out by a commander in an unknown country to pick out a good position for camp and outpost, and to report upon his return the military features of the site selected. On visiting the ground selected, his eye can only take in a very limited portion from any one position, and even with the most careful examination from various points he would get only a very general idea of the larger features. If he had made the simplest sketch, however, while on the ground, even if it were not very accurate, it would enable him to give his commander as clear an idea as he himself had gotten of the position. But a report based on an accurate detailed sketch would be complete and would enable him to issue workable orders for camp and outpost. It is almost impossible to organize and carry out marches, reconnaissances, or concentrations without maps upon which to base the orders.

9. Almost all classes of maps have some military uses. For example, an ordinary map showing the location of important towns, large rivers and roads, is useful for arranging the concentration of large bodies of troops, or for following the opera-

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tions of a campaign, but it is far from being in sufficient detail for the purposes of those who plan or study the smallest operations of war. Complete military maps, on the contrary, must give both horizontal and vertical relations of the ground and must also show all military features within the area represented.

10. *A military map, therefore, is one which shows all features of the ground that can influence military operations.*

To *Read a Map* is to get a clear mental picture of the area represented, just as it would appear to you if you were looking at the ground itself.

Before you can get this vivid mental picture of a portion of country by looking at the corresponding map, you must be able to tell how far apart on the ground are the objects shown on the map. The first thing then to learn about a map is how great a distance on the ground, a given distance on the map represents. This is known when you know the scale of the map.

Scales of Maps

11. Every map is drawn to scale, that is every distance on it must bear a fixed proportion to the corresponding distance on the ground.

If one inch on the map represents a mile on the ground, then two inches on the map will likewise represent two miles on the ground. For brevity we usually write the expression: *"One inch on the map represents one mile on the ground,"* thus: "1″ = 1 MILE"; so remember that this is the meaning when you see in this book expressions like this one.

When the word *"distance"* is used, horizontal distance is meant, and vertical distance to any point is called *"elevation"* or *"depression,"* depending on whether this point is higher or lower than the one from which you are measuring.

For instance when you say that two points are ten miles apart, you mean that the horizontal distance between them is ten miles.

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In referring to such distances between cities or towns, that by the shortest main road is usually intended. In going from one of these towns to the other, you may go up and down several hills so that the actual length of travel measured along the surface of the ground is considerably greater than ten miles. It is well to keep this in mind in figuring distances between places shown on a map. The map distance shows only the horizontal distance.

It will undoubtedly occur to you at once that we must have not only a scale to show horizontal distances, but also one to show relative elevations. This difference of elevation between points is shown on maps in one of two ways:

(a) By contours, par. 22, and

(b) By hachures, par. 28.

Methods of Showing the Scale of a Map

12. There are three ways in which the scale of a map may be represented.

(1) By statement in words and figures, as $3'' = 1$ mile; $1'' = 200$ feet.

(2) By a graphical scale. A graphical scale is a line drawn on the map divided into equal parts, each division being marked not with its actual length, but with the distance which it represents on the ground.

(3) By what is called the natural scale, or the representative fraction (abbreviated to "R. F.").

Each of these ways of showing the scale of a map has its advantages and a carefully made map will usually be found to have its scale shown in all three ways.

Every map should have a graphical scale because this gives true readings, no matter how the size of the map is changed in reproduction or due to weather conditions; whereas the R. F. and the number of inches per mile placed on the original map are no longer true if the size is altered. The R. F. is important, how-

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ever, because it is intelligible to persons unfamiliar with the units of distance used in making the map. An expression of the scale in words and figures is also valuable, because rapid mental estimates can be made of the distances between points on the ground by estimating the number of inches between these points on the map.

The failure to put the proper scales on a map often decreases its usefulness. For instance a scale showing only miles and half miles could not be used readily in figuring ranges in yards with reasonable correctness until it is converted into a scale of yards.

The representative fraction of a map is one whose numerator shows the units of distance on the map and whose denominator shows the same units of horizontal distance on the ground, thus: $\frac{\text{map}}{\text{ground}}$.

The representative fraction may be found on maps written in one of several different ways, thus R. F. $= \frac{1}{63360}$, 1:63,360, or 1:63360. All of these are equivalent expressions, meaning that one unit of distance on the map represents 63,360 of the *same units* of distance on the ground.

The representative fraction is synonymous with the term *"Scale of the Map,"* therefore, if the scale be changed, the representative fraction will be changed in exactly the same manner and amount. To increase the representative fraction, its denominator is *decreased.* For the same reason the greater the distance on the ground represented by an inch on the map, the smaller is the scale of the map. The greater the dimensions of the map to represent a given area, the larger is the scale, that is the "R. F.," and the smaller the denominator of the latter.

The representative fraction is the form of the scale used for solving all problems in construction of scales.

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13. Graphical scales are of two kinds, depending on the purpose for which they are constructed:

(1) Working scales,

(2) Reading scales.

A working scale is used in making a sketch or map and shows graphically the value of tens, hundreds, etc., of the units of distance used in making the map or sketch. For example, if distances were measured by counting paces or taking the time of a horse trotting, in making a sketch, then it would be necessary to construct a scale of paces or minutes of horse's trot on the desired scale of the sketch. This enables you to lay off on the sketch, distances measured thus, directly from the working scale without the necessity of figuring at each halt how many inches on the sketch are equal to the number of paces or minutes passed over.

A reading scale shows the distance on the map corresponding to even tens, hundreds, etc., of some convenient and well-known unit of measure, such as the foot, yard, or mile. For example, figure 1 shows a reading scale of yards reading to five hundred yards on the main scale and to one hundred yards on the extension. A scale may be both a working and a reading scale, when the unit of measure used in making the sketch is a well known length, such as the yard. The reading scale of maps of one country are often not satisfactory to persons of a different nationality, because of their unfamiliarity with the length of the units of distance used. An officer coming into possession of such a map would be unable to get a correct idea of the distance between points represented. He would find it necessary to convert the scale into familiar units, as yards or miles. See problem No. 4, p. 16.

It will readily be seen that a map's scale must be known in order to have a correct idea of distances between objects represented on the map. This is essential in determining lengths

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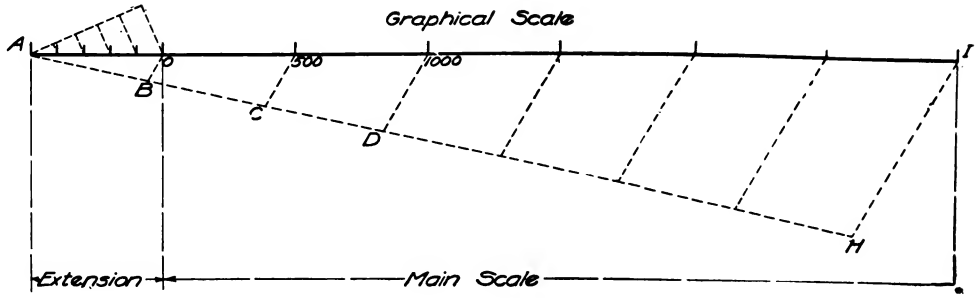

FIG. 1

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of march, ranges of small arms and artillery, relative length of marches by different roads, etc. Therefore, if under service conditions, you should have a map without a scale or one expressed in unfamiliar units, you would first of all be compelled to construct a graphical scale to read yards, miles, etc., or one showing how many miles one inch represents. Or, if you are required to make a sketch by pacing, it would be necessary to construct your scale of paces on the proper representative fraction.

Construction of Scales

14. The best way to become thoroughly familiar with the scales of maps is to solve problems relating to their construction.

The principles of scale construction are simple, but should be thoroughly understood so that if your map does not have the scale on it which you need, you can make one in a few minutes. Scale construction is also important in military sketching, especially for determining the scale of your paces or strides or of the rate of your horse's travel.

On every map, even if it has no scale at all, you will find certain information from which you can figure out its scale. This lack of a scale is especially liable to occur in case of maps you will get from the enemy in the present war. These may be only fragments of the original map showing no scale whatever.

15. In the construction of scales, the following steps are taken:

(1) Find out from information on the map its representative fraction. This is an essential step in every complete scale problem. There are, however, many simple problems where this is not necessary. For example, suppose you want to construct a scale to read yards on a map whose scale is six inches to one mile. (R. F. $= \frac{1}{10560}$.)

Solution: Lay off six inches on the map and this will show a mile or 1760 yards, giving 17 equal spaces, each of which

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represents 100 yards and one space which shows 60 yards. This can be readily laid off with a ruler, divided into inches and tenths. If no such ruler is at hand, the line can be divided into any desired number of parts, as described in the footnote.* See figure 1.

(2) Next find the length in inches of the unit of measure for which you want to construct the scale, as for instance a pace, stride (par. 49), one minute of horse's trot (par. 86).

For units whose length in inches is known, such as the yard or foot, this step becomes self-evident. For units whose length is not previously known, such as your pace, you must determine them. The units you require in sketching will probably be limited to your own pace (or stride, which is a double pace), and the distance in inches which a horse travels in one minute at the walk or trot.

(3) Next find how many of the units which are to be shown by this scale correspond to one inch on the map.

As soon as you know the Representative Fraction (1) and the length of unit (2), (3) is found by a simple substitution.

Problem 1. Suppose the Representative Fraction is $\frac{1}{21120}$ (1) and you wish to construct a scale of yards.

Then, 1 yard = 36 inches (2), and 1 inch on the map = $21120 \div 36 = 586.66$ yards on the ground. (3)

(4) Finally, find the length in inches on the map corresponding to an even number of tens, etc., of these units of distance on the ground. Thus, suppose a scale about 6 inches long is

* To divide a line (AI) into a given number of equal parts, as for example 7, proportional to the parts into which another line is divided, draw a line (AH) making any convenient angle with (AI), and lay off on it 7 equal convenient lengths so as to bring (H) approximately opposite (I). Join (H) and (I) and with a ruler and triangle draw the intermediate lines through (B, C, D), etc., parallel to (HI). These lines divide (AI) into 7 parts proportional to the parts into which the line (AH) was divided. The left space, called the extension, is similarly divided into 5 parts each equal to 100 yards.

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desired: 6 inches on the map $= 6 \times 586.66 = 3519.96$ yards on the ground, so that you assume 3500 to be the number of yards to be shown. The question then is, how many inches show 3500 yards.

Since 1 inch = 586.66 YDS., as many inches are required to show 3500 yards as 586.66 is contained in 3500, or $3500 \div 586.66 = 5.96$ inches. Divide 5.96 inches into 7 equal parts each to show 500 YARDS (See footnote, p. 14).

Problem 2. R. F. $\frac{1}{10000}$ length of stride 60 inches. Construct a working scale of strides.

Solution: 1 STRIDE = 60 INCHES. 1 inch = 10000 INCHES $= \frac{10000}{60}$ STRIDES.

Suppose a 3 inch scale is desired. 3 inches $= 3 \times \frac{10000}{60} =$ 500 STRIDES. Construct the scale by dividing up three inches into 5 parts of 100 STRIDES each by the method of figure 1.

Problem 3. A sketcher's horse trots one mile in 8 minutes. Construct a scale of minutes and quarters, R. F. $\frac{1}{21120}$.

Solution: 8 MINUTES = 63360 INCHES.

$$1 \text{ INCH} = \frac{8}{63360} \text{ MINUTES.}$$

From which 21120 INCHES $= \frac{21120 \times 8}{63360}$

MINUTES $= {}^{8}/_{3} = 2\frac{2}{3}$ MINUTES. Since 1 inch = 21120 inches, we have:

1 inch $= 2\frac{2}{3}$ MINUTES.

6 inches $= (6 \times 2\frac{2}{3})$ MINUTES = 16 MINUTES.

Construct the scale by dividing the 6 inch line into 16 equal parts for MINUTES, and the left one of these spaces into 4 equal parts to read quarters of a minute.

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R. F. Not Given

16. *Problem 4.* An American officer in Germany secures a map showing a scale of 1 centimeter = 1 KILOMETER.

Required (a) the R. F. of this map (100 centimeters = 1 meter; 1000 meters = 1 kilometer).

Solution: $\frac{1 \text{ cm}}{1 \text{ KM}} = \frac{.01 \text{ m}}{1000 \text{ M}} = \frac{1}{100000} = \text{R. F.}$

(b) How many inches to the MILE in this scale?

(c) Construct a reading scale of MILES for this map.

Problem 5. (Where a map has a graphical scale on which the divisions are not in even parts of inches and are marked in ground distances of some unfamiliar unit as kilometers, meters, chains, etc. It is required to construct a graphical scale in familiar units.) By measurement on the scale of a German map, 1.08 inches reads 1 KM. (a) What is the R. F. of the map? (b) Construct a graphical scale to read YARDS. Solution: 1.08 inches = 1 KM = 1000 METERS (1 m = 39.37 in.). 1.08 inches = 39370 INCHES or 1 inch = 36453 INCHES, or R. F. = $\frac{1}{36453}$; whence construct graphical scale as in par. 15.

Problem 6. (Where a map has no scale at all. In this case measure the distance between two definite points on the ground represented, by pacing or otherwise, and scale off the corresponding map distance. From this find the R. F. and construct the graphical scale as above.) For example, suppose the distance between two road crossings, identified on map and ground, is found to be 500 PACES (31 inches each), and on the map to be ¾ inch. In this case ¾ inch = (500 × 31) INCHES.

$$1 \text{ inch} = \frac{500 \times 31}{\frac{3}{4}} = 20666.66 \text{ INCHES; R. F.} = \frac{1}{20666.66}$$

From this R. F. a scale of yards is constructed as in par. 15.

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Changing the Scale or the Area of Maps

17. Note the difference between increasing or decreasing *the scale (linear dimensions)* of a map, and its *size (area)*. To double the size of a map whose sides are six inches and 4 inches ($6 \times 4 = 24$ square inches), the reproduction would be 48 sq. inches that $6\sqrt{2}$ by $4\sqrt{2}$ on the sides. To reduce a 9 inch by 6 inch map to $\frac{1}{3}$ its size (area), the sides would be $\frac{9}{\sqrt{3}}$ and $\frac{6}{\sqrt{3}}$. $\frac{9}{\sqrt{3}} \times \frac{6}{\sqrt{3}} = \frac{54}{3} = 18 = \frac{1}{3}$ of 54. The general rule is that to change the area of a map any multiple, as 2 times, 3 times, $\frac{1}{3}$ times, its original original area, each of the linear dimensions is multiplied by the square root of the multiple as $\sqrt{2}$, $\sqrt{3}$, $\frac{\sqrt{1}}{3}$.

Problem 7. A map, R. F. $\frac{1}{6000}$, is enlarged so that the distance on the map between two towns A and B is 3 times as great as on the original. What is the new R. F.? Answer. R. F. $\frac{1}{2000}$, (R. F. multiplied by 3).

Problem 8. A map has R. F. $\frac{1}{8000}$. The original area of the map was 8 by 16 inches. What is the new R. F., if its area is four times as large as that of the original?

Solution: $\frac{1}{8000} \times \sqrt{4} = \frac{1}{8000} \times 2 = \frac{1}{4000} =$ R. F.

Correction of Erroneous Scales

18. It sometimes happens that in making a sketch an error exists in the length of the unit of measure that is not discovered until later. The question is then (1) how to find the true scale of the map as made, and (2) how to correct the working scale so it will be true for the future work.

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Problem 9. An officer is ordered to make a position sketch, scale 6 inches = 1 MILE. He uses a working scale of 62 inch strides. Afterwards he finds that his stride is actually 58 inches.

Required: (a) What is the R. F. of the sketch actually made, and (b) is the scale larger or smaller than ordered?

Solution: (a) R. F. assumed $\frac{1}{10560}$. Since his stride was shorter than assumed, in plotting any given distance on the sketch (as 1 inch), he had actually passed over a shorter distance on the ground than he thought. Consequently his true R. F. would have a smaller *denominator* in the proportion of the true and assumed rates, 58 to 62.

$10560 \times \frac{58}{62} = 9878.70$ INCHES.

The true R. F. of sketch was $\frac{1}{9878.70}$.

(b) The R. F. $\frac{1}{9878.70}$ is larger than R. F. $\frac{1}{10560}$, having a smaller denominator, and therefore the scale of the sketch as made is too large.

Problem 10. A mounted sketch is made on the scale of 3 inches = 1 MILE, with a horse rated at 5.5 MINUTES = 1 MILE. The true rate of the horse is 1 MILE in 6 MINUTES.

Required: The true R. F. of the sketch.

Solution: Since the horse took longer to pass over a mile, than was thought, he traveled slower than he was rated. There was accordingly too short a distance covered at the end of any given number of minutes. Hence the distance on the ground corresponding to any plotted map space, say one inch, was less than supposed, or the denominator of the R. F. is really less than 21120, in the proportion of the two rates: $21120 \times \frac{5.5}{9} =$ 19360. The true R. F. is $\frac{1}{19360}$.

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Problem 11. A sketcher is ordered to make a sketch on the scale R. F. $\frac{1}{21120}$. He supposes he takes a 29 inch pace and uses this for his working scale. Afterwards he finds that a distance of 4000 yards scaled from his sketch measures on the ground 4125 yards.

Required: (a) His true length of pace.

(b) The true R. F. of the sketch as made.

$\frac{4000 \times 36}{29} = 4965 =$ number of paces taken in traveling the distance, *whether he assumed the correct length of pace or not.* But inasmuch as the corresponding distance on the ground measured 4125 yards, therefore, dividing this distance by the number of paces taken in passing over it, gives the true length of each pace: $\frac{4125 \times 36}{4965} = 29.9$ inches = actual length of pace.

(b) If the distance of 4000 yards scaled from the sketch actually measured 4125 yards on the ground, the sketch is smaller than intended and the R. F. $\frac{1}{21120}$ is too large and must be decreased in the proportion of these two distances, i. e., its denominator must be increased. (See par. 12.) Therefore,

$\frac{1}{21120} \times \frac{4000}{4125} = \frac{1}{21780} =$ true R. F.

General Scale Problems

19. *Problem 13.* Construct a working scale of paces for a map on the scale of 12 inches = 1 MILE, one hundred and twenty paces being equal 100 yards.

Problem 14. A reduction of the General Staff map of France is published on a scale of R. F. $\frac{1}{200000}$,

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(a) Construct a graphical scale to show 15 miles on this map.

Answer. 4.752 inches = 15 MI. Divide 4.752 inches in 15 parts, each to read 1 mile.

(b) Construct a graphical scale to show 15 kilometers (1 meter = 39.37 inches, 1 kilometer = 1000 meters).

Answer. 2.95 inches = 7.5 cm = 15 KM. Divide the line 2.95 inches long into 15 equal parts, each to show 1 KM.

Problem 15. A map was drawn on the scale R. F. $\frac{1}{10000}$ but in reproduction its dimensions were changed so that 800 yards on the ground scales 875 yards on the map.

Required: What is the correct R. F.?

Answer. $1 \div 9143$.

Problem 16. Draw a suitable scale of yards for a map 10 by 12 inches to show an area of 5 by 6 miles.

Scaling Distance from a Map

20. Having considered the scale relation and the construction of scales, it is well to mention the use of scales in taking distances from a map. Distances may be measured on a map in the following ways:

1st. Apply a piece of straight edged paper to the distance between two points to be measured and mark the distance on the paper. Now apply the paper to the graphical shown in figure 2 and read the number of yards on the main scale adding the number on the extension with a total of 500 + 25 = 525 yards.

2nd. Take the distance A B, figure 2, off with a pair of dividers and applying the dividers, thus set, on the graphical scale read off 525 yards.

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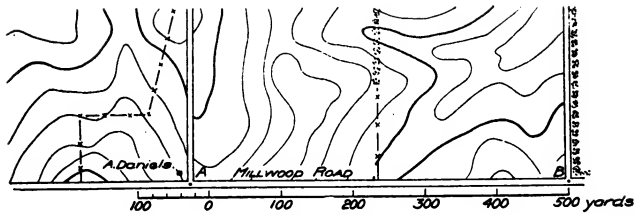

FIG. 2

3rd. Use an instrument called a map measurer, figure 3. Setting the hand on its face to read zero, roll the small wheel from A to B. Now roll the wheel back to zero in an opposite direction along the graphical scale, noting the number of yards passed over on the scale. Or, having rolled from A to B, note the number of inches on the dial and multiply this by the number of miles per inch given on the map. *A map measurer is especially valuable for use in map problems and war games.*

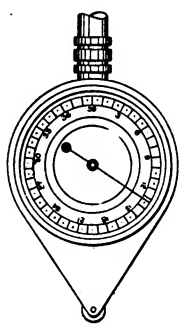

FIG. 3

4th. Apply scale of inches to the line and multiply the number of inches between the points by the number of miles per inch given on the map.

5th. Copy off the graphical scale on the edge of a piece of paper, and then apply this directly to the map.

If the line to be measured changes direction, the same methods are used.

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CHAPTER II

Methods of Representing Slopes and Elevations

21. We have seen how horizontal distances on the ground are shown on a map. The next thing necessary to learn is how to show elevations and depressions. This is of great importance in military maps because of the necessity of showing the shapes, heights, and slopes of hills.

Elevations are shown in one of two ways:

(a) By contours,

(b) By hachures. (See par. 28.)

If the earth were cut by a series of horizontal planes at equal vertical distances apart, the lines thus cut from the earth's surface would be contours. (Figure 4.) The vertical distance of contours from each other is called the vertical interval (abbreviated V. I.). On any given map, the V. I. has a constant value, as for instance 10 ft., 20 ft., etc. The representations of these lines on a map are also called contours and this is what is usually meant by the word "*contour*" (Figure 5). When we speak of a point on the 100-ft. contour, we mean that this point is 100 feet above the zero contour or datum plane. The relations between contours on the ground and contours on the corresponding map are shown in figures 4 and 5.

22. Suppose that the island shown in figure 4 was once entirely covered by water and that due to an earthquake the lake fell until the highest peak appeared above the water. Later a succession of similar falls of the water level of 20 feet each occurred until now the island stands more than 100 feet out of the lake and at each 20-ft. elevation a distinct water line is left. These water lines are perfect contours referred to the lake as reference (or datum) plane. It will be observed that on the gentle slope along F-H the 20-ft. contour is far from the lake and

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FIG. 4

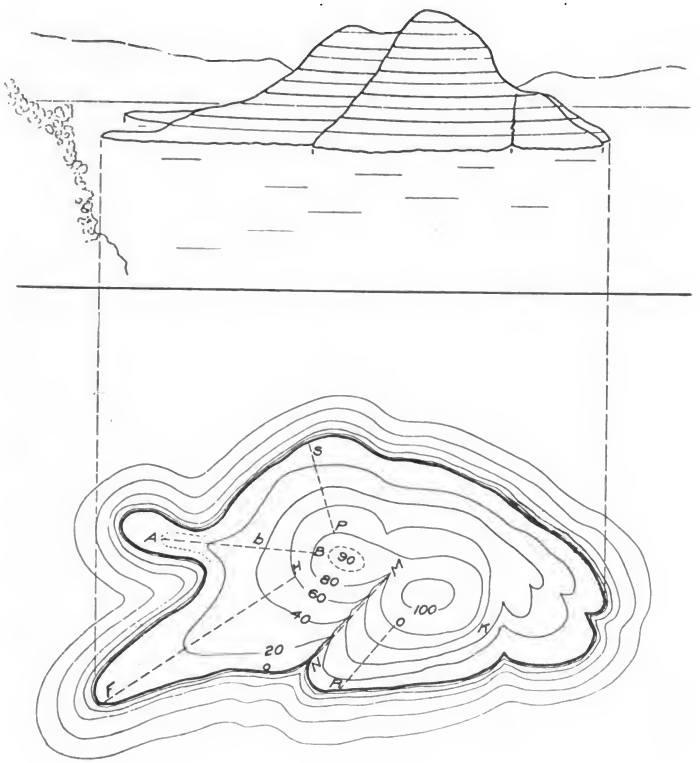

FIG. 5

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from the 40-ft. contour. On the steep slope at R just above the water the contours are very close together on the map.

It will also be noted that the shape of the contours in figure 5 gives a clear idea of the form of the island shown in figure 4. They also give an exact representation of the two peaks, the stream M-N, the saddle (or col) M, the water shed from F to H, the cliff at K, and the slope of the ground at all points.

The cone, hemisphere, and concave cone may be considered as examples of the three kinds of hills found in nature, namely, those with uniform slopes, those with gentle slopes at the top growing steeper towards the bottom, and those with steep slopes towards the top growing gentler towards the bottom.

23. The following points should be remembered about contours:

(1) Contours spaced equal distances apart on a map represent a uniform slope.

(2) Contours spaced far apart on a map indicate gentle slopes.

(3) Contours close together on a map indicate steep slopes.

(a) A *water shed or spur,* along which the water divides, flowing away from it on both sides, is indicated by the higher contours bulging out toward the lower ones. F-H figures 4 and 5.

(b) A *water course, or valley,* along which rain falling on both sides of it joins in one stream, is indicated by the lower contours bending out sharply toward the higher ones. (M-N figures 4 and 5.)

(c) Contours of different elevations which unite and become a single contour, represent *a vertical cliff.*

(d) Two contours of different elevations which cross each other represent an *overhanging cliff.*

(e) A closed contour represents either a *hill top* (crest), as P-B figure 5, or a *depression.* A hill top is shown when the

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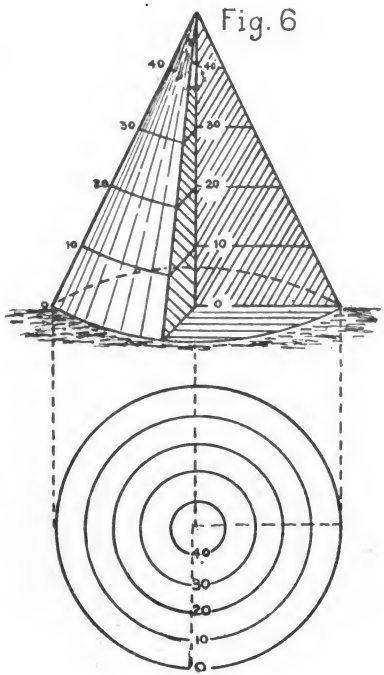
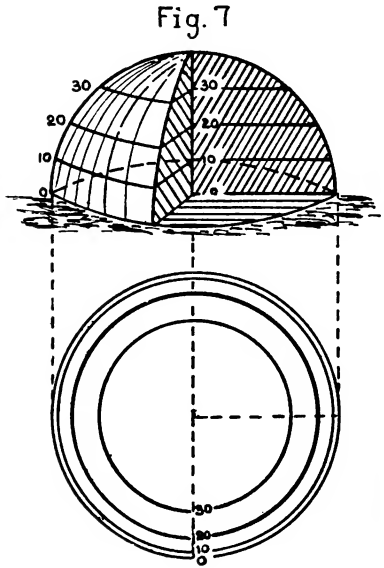
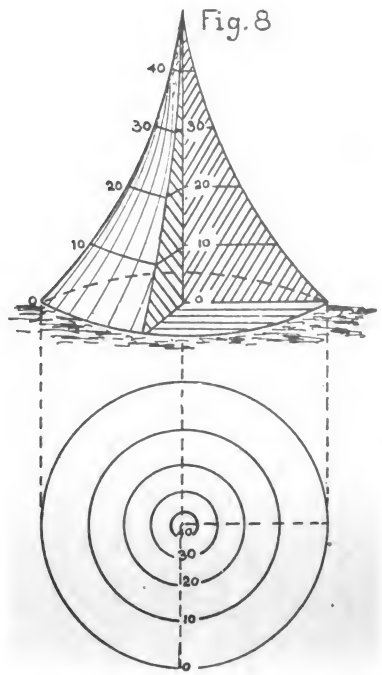
Plate 3







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smallest closed contour is higher than the adjacent contour, and a depression when the smallest closed contour is lower than the contour next to it.

(f) *A saddle (or col)* is shown at a point when two contours of greater elevation are on two sides of it, and two of lower elevation are on the other two sides, as at M figure 5. M is a saddle between the two peaks 90 and 100.

Representation of Slopes

24. Slopes are usually given in one of three ways: 1st, in *degrees;* 2nd, in *percentages;* 3rd, in *gradients.*

1st. A one degree slope means that the angle between the horizontal and the given line is 1 degree (1°).

2nd. A slope is said to be 1, 2, or 3 percent, when 100 units horizontally correspond to a rise of 1, 2, or 3 of the same units vertically.

3rd. A slope is said to be *one on one* (1÷1), *two on three* (2÷3) when one horizontal unit corresponds to one vertical, three horizontal correspond to two vertical. The numerator usually refers to the vertical units. Degrees of slope are usually used in military matters; percentages are often used for roads, almost always for railroads; gradients are used for steep slopes, and usually for dimensions of trenches.

Since 1° gives a rise of 1 foot at 60 feet (approximately), then 1° slope is equal to a gradient of 1 on 60 ($\frac{1}{60}$). 2° to 2 on $60 = \frac{1}{30}$. 3° to 3 on $60 = \frac{1}{20}$ etc. These values are useful for quickly giving an idea of the various degrees of slopes corresponding to gradients, and for converting one form of expression into another.

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Slope Equivalents

25. The distance on a map between two adjoining contours is called the *slope equivalent,* or *map distance* (abbreviated M. D.) of those contours apart. This is called slope equivalent because no matter where this distance on the particular map is found between any two adjacent contours of different elevations, it indicates a certain definite slope at that point. Since this map distance between adjoining contours depends on the slope of the ground being greater as the slope is gentler, it follows that a scale of these M. D.'s can be made with which slopes can be read from the map exactly as we would read horizontal distances with a graphical reading scale of yards. Such a scale is called a scale of slope equivalents or map distances and is shown in figure 9. It is often necessary to make one of these scales for the reason that maps frequently have no such scale on them and they are of much value

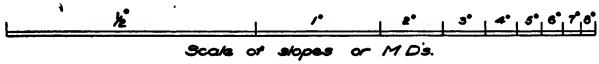

Fig. 9

in studying military problems. In fact it is frequently more important for a military commander to know the slopes of hills correctly than to know the exact distances apart of the places shown on the map. He must therefore have a scale of slope equivalents on his map at all times.

In a triangle whose base is 57.3 feet and whose vertical side is 1 foot, the angle opposite the vertical side is 1 degree. This principle is used as the basis for making scales of slope equivalents. Up to slopes of about 20 degrees it is nearly enough correct to cause no appreciable error on maps which are used for military purposes.

Rule: To construct a scale of slope equivalents (M. D.'s) for a map on which it is not shown, take the distance in inches corresponding to one degree of slope. Multiply this by the

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vertical interval (V. I. in feet) and by the R. F. The result is the M. D. in inches, for one degree slope. Divide this value by two, three, four to get the M. D. for two degrees, three degrees, four degrees, and lay off these distances on a line to show M. D.'s corresponding to each degree from one degree upward, see figure 9.

The equation showing the relation of M. D.'s scale of map and vertical interval may be written thus; M. D.$\times$S = R. F.$\times$V. I.$\times$ 688 . . . . . (1). If now M. D. and slope in degrees on two or more maps are assumed to be fixed values, their product will also be a constant quantity fixed in value. That is, if F. R. (scale) is increased, the V. I. must be proportionately decreased and *vice versa*. This principle is of great value in map reading and sketching, because on all maps made on such a system, a given map distance between adjacent contours represents the same slope.

The normal system of scales prescribed in Field Service Regulations for maps and sketches is based on the relations described above.

26. "In the field the maps available for general use are on a small scale. Those of our own country are prepared by the Geological Survey on a scale of 1 is to 62,500 (approximately 1 inch to the mile), with 20-ft. contours. These maps are supplemented by field maps or sketches prepared from day to day. For facility in reading, military maps are made according to a uniform system of scales and contour intervals, as follows.

1 inch to 1 mile, V. I. 60 feet,
3 inches to 1 mile, V. I. 20 feet,
6 inches to 1 mile, V. I. 10 feet,
12 inches to 1 mile, V. I. 5 feet.

As a rule, road sketches are made on a scale of 3 inches to 1 mile, V. I. 20 feet: Position and outpost sketches, 6 inches to 1 mile, V. I. 10 feet. The 1-inch map is used for extended operations; the

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12-inch map for the war game or for the discussion of operations at maneuvers and in siege operations."*

On all these maps made according to the normal system, the M. D. for 1 degree slope is .65 inch, found substituting in the equation above (1), as follows: Take the 6-inch scale. M. D. = $\frac{1}{10560} \times 10 \times 688 = .65$ inch. The same is true of 1-inch and 3-inch scales.

The scale of M. D.'s for maps on the normal system is as follows:

1 degree .65 inch.
2 degrees .325 inch.
3 degrees .217 inch.
4 degrees .163 inch.
5 degrees .13 inch.

These are shown in figure 9.

27. *"Practicability of slopes.* Slopes from 0° to 5° are practicable for maneuvering all arms, singly or combined.

On slopes from 5° to 10° all arms can still be maneuvered, but with increasing difficulty.

On slopes from 10° to 15° all arms can be moved up or down.

Slopes from 15° to 30° are practicable for small detachments only.

On slopes from 30° to 45° foot troops can move with difficulty.

War material can be dragged up any slope.

* From F. S. R.

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Slope fractions	Degrees	Operations
1/50	1	Maximum for railroads.
1/20	3	Maximum for first-class roads.
1/12	5	Practicable for all arms. Somewhat difficult for cavalry to charge descending.
1/10	6	Maximum for cavalry charge in mass ascending. Infantry in close order descends with some difficulty.
1/8	7	Cavalry can descend at a trot.
1/7	8	Not practicable for heavily loaded vehicles.
1/6	9-½	Field artillery can no longer maneuver.
1/4	14-15	Maximum for cavalry charge in mass ascending.
1/3	18-½	Light vehicles can ascend.
1/2	26	Individuals and mules can ascend or descend.
1/4	45	Foot troops can ascend or descend aided by hands.''*

*From F. S. R.

Problem 1. Suppose you have a given slope between two contours where the slope equivalent is 1 inch. How is the scale changed, if for the same contour interval and slope the slope equivalent should be 2 inches?

Solution: V. I. and slope are constant, hence the slope equivalent varies directly with the scale, but the slope equivalent is doubled and therefore the scale is doubled.

Problem 2: An M. D. of 2 inches on a certain map represents a slope of 5 degrees. How much must the scale of the map be altered for a distance between two adjacent contours of 5 inches to show 3 degrees with the same contour interval as before?

Answer: The second representative fraction equals three halves of the first representative fraction.

Problem 3: (The scale of the sketch [figure 30] is 6 inches equals 1 mile.) What is the steepest slope on the ground between A and B? What is the percentage of this slope?

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Solution: Take off on a slip of paper the distance between the two adjacent contours on this line which are closest together and apply this to the scale of slope equivalents, figure 9.

Elevations Represented by Hachures

28. A second method of representing on a map, elevations on the ground is by means of vertical lines called hachures. figure 10. This method is not used in the United States and most of the countries of Europe have abandoned it. Germany, however, still uses hachures for its small scale maps. Figure 10 shows a full size copy of the 1 to 100000 German military map of Metz and vicinity and it should be thoroughly understood by every American military student. By comparing the Metz map, figure 10, with the same area reduced from the 1 to 25,000 map, figure 11 on which contours are used, it will be seen that the contours give not only the exact elevations, but a much clearer idea of the slope of the ground than the hachures. Where no hachures are found on a hachured map, the ground is either a hill top or a flat low land. Slopes of the ground are roughly indicated by the varying heaviness and nearness of the hachures. The darker the section the steeper is the slope. It often happens that a flat area is only known to be a hill top or valley by referring to the surrounding features. Usually, however, figures indicate the heights of important points. For instance on the road between Hautegreve and Grigy there is a very steep place in the road opposite Pierrejeux. This is indicated, not only by the heaviness of the hachures, but also by the fact that the road branches into two parts, one of which is much longer than the other, evidently intended to be used for wagons with heavy loads.

At the present time, the importance of being able to read a hachured German map is greater than ever before. Figure 19 shows the principal conventional signs used on these maps and the

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table. par. 37, shows the English equivalent for the German words usually found on those maps.

A German hachured map on the scale of 1 to 100000 will be the one most frequently found and should be thoroughly understood. It is on a much smaller scale than our maps in common use. For

FIG. 10

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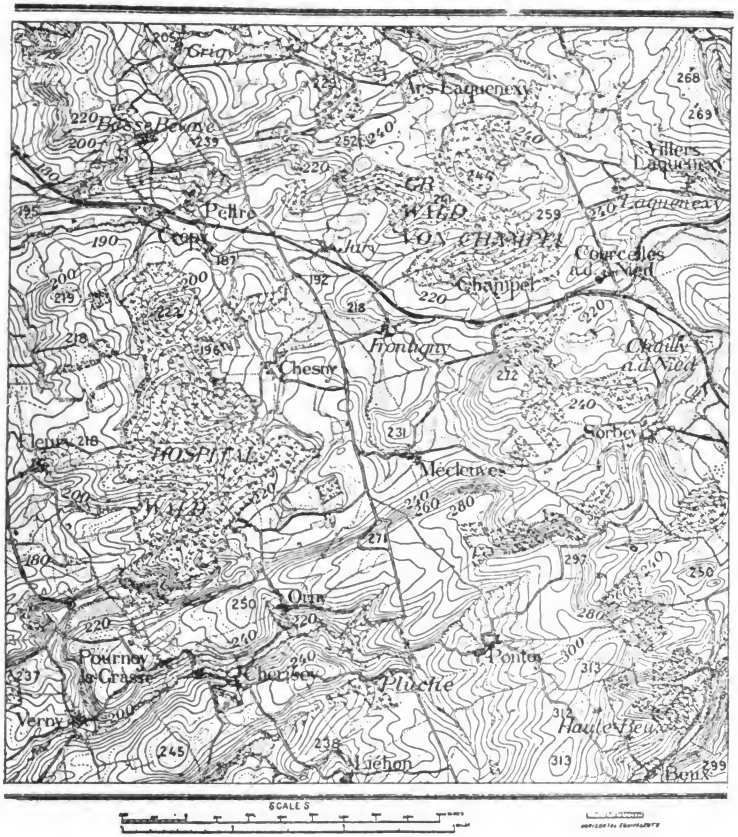

FIG. 11

instance the Geological Survey map is 1 to 62500, or a trifle larger than 1 inch to the mile, whereas this map is 1 to 100000 or approximately 1 inch equals 1½ miles.

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CHAPTER III

Direction on Maps

29. Having given the means used for determining horizontal distances and relative elevations represented on a map, the next step is the determination of horizontal directions. When these three facts are know of any point, its position is fully determined.

The direction line from which other directions are measured is usually the true north and south line (known as the *true meridian*) ; or it is the line of the magnetic needle, called the *Magnetic Meridian.* These two lines do not usually coincide, because at points of the earth's surface the true meridian is the straight line joining the observer's station and the north pole of the earth whereas the direction of the magnetic meridian varies at different points of the earth, at some places pointing east, and at others west, of the true pole.

The angle measured at the north point which the magnetic meridian makes with the true meridian at any place on the earth is the *magnetic declination* at that place. Although the magnetic needle is more nearly fixed in position with respect to angles in the horizontal plane than any other known object, yet at any point on the earth it varies from year to year in what is known as secular variation, so called because the change continues through a series or cycle of years. The needle also has a slight daily variation, but this is of no importance in military sketching and map reading.

The *Azimuth of a Line* is the horizontal angle which that line makes to the meridian measured from the north point clockwise (eastward) around a circle.

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The *Bearing of a Line* is the angle less than 90 degrees which that line makes with the meridian. Bearings are read thus, N 15° 10′ E, or S 20° 30′ W.

When these measurements are made from the true meridian they are called *true* azimuths or *true* bearings. When measurements are made from the magnetic meridian they are called *magnetic* azimuths or *magnetic* bearings.

It is important to know the relation between true and magnetic meridians, because maps usually show the true meridian and an observer takes a reading with a magnetic compass and thus from the magnetic meridian. Figure 12 shows the usual type of box compass furnished to officers. It has marked on its face the four cardinal points, N, E, S and W, and a circle which should preferably be graduated into degrees to read from zero clockwise around the circle to 360°. That is, an observation to the east should be read 90°; one to the south, 180°; and one to the west, 270°.

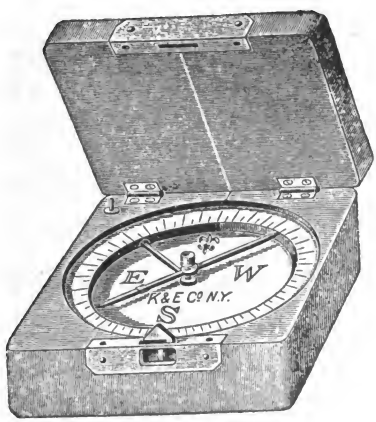

FIG. 12

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Methods of Orienting a Map

30. In order that directions on the map and on the ground shall coincide, it is necessary for the map to be oriented, that is, the true meridian of the map must lie in the same direction as the true meridian through the observer's position on the ground. Every road, stream or other feature on the map will then be parallel to its true position on the ground, and all the objects shown on the map can be identified and picked out on the ground.

1st Method. When the map has a magnetic meridian marked on it, as on the Leavenworth map. Place the sighting line of the compass, *a b*, figure 13 (i. e., the north and south line of the compass face), on the magnetic meridian of the map and rotate the map horizontally, until the north end of the needle points towards the north of its circle, whereupon the map is oriented.

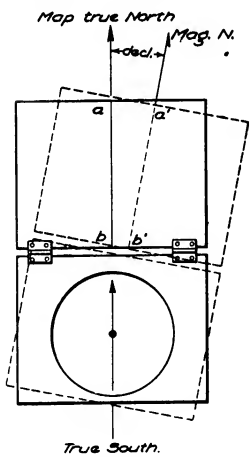

Fig. 13

Where only the true meridian is on the map: Construct a magnetic meridian, figure 13, if the declination is known, as follows: Place the true meridian of the map directly under the magnetic needle of the compass, while it is pointing to zero, then, keeping the map fixed, rotate the north of the compass circle *in the direction of the declination of the needle* until the needle has passed over an angle equal to the declination. Draw a line on the map in the extension of the N-S line of the compass circle (*a' b'*), and this will be a magnetic meridian. Having constructed the magnetic meridian on the map, orient it as under the 1st method.

If the magnetic declination at the locality is not more than 4 or 5 degrees, the orientation will be given closely enough for map reading purposes by taking the true and magnetic meridians to be identical.

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2nd Method. When neither the magnetic nor the true meridian is on the map: (a) If you can locate on the map your position on the ground, and can identify another place on the map which you can see on the ground, join these two points on the map by a line and hold the map so that this line points toward the distant point seen on the ground, whereupon the map is oriented. (b) If you can place yourself *on the line* of any two points visible on the ground and plotted on the map, rotate the map until the line joining the two points on the map points toward the two points on the ground, whereupon the map is oriented.

To Locate on a Map Your Position on the Ground

31. (1) *When the map is oriented by compass:* (a) Sight along a ruler at an object on the ground while keeping the ruler on the plotted position of this object on the map, and draw a line toward your body. Do the same with respect to a second point visible on the ground and plotted on the map. The intersection of these two points is your map position.

(2) *When the map is oriented by the 2nd method* (b): Sight at some object not in the line used for orientation, keeping the ruler on the plotted position of this object and draw a line until it cuts the direction line used for orienting the map. This is your position on the map. Any straight line on the map such as fence, road, etc., is useful for orienting and thus finding your position.

Usually your position may be found by characteristic landmarks, as cross roads, a crossing of railroad and highway, a junction of streams, etc.

Travelling by Map

32. Having learned to orient a map and to find your position on it, you should secure a map of your vicinity and practice moving along roads at the same time keeping the map constantly oriented and noting exact features on the map as they are passed

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on the ground. This practice is of the greatest value in learning to read a map accurately; to estimate distances, directions and slopes correctly. The scale must be constantly kept in mind during this work, to assist in identifying your position at all times. Check off on the map the prominent points passed, such as bridges, cross roads, hill tops, villages, etc., and be sure that you identify correctly all objects of the terrain in your vicinity. You will find it difficult at first to constantly judge your position correctly, and from time to time will "lose yourself." When this occurs try to pick up your position again by careful observation of landmarks, assisted by an estimate of the map distance you should have traveled, at your present rate, from some point passed at a known hour.

True Meridian

33. The approximate position of the true meridian may be found as follows: Point the hour hand of a watch toward the sun; the line drawn from the pivot to the point midway between the outer end of the hour hand and XII on the dial will point toward the south, figure 14. To point the hour hand exactly at the sun, stick a pin, or hold up a finger, as shown in figure 14, and bring the hour hand into the shadow. At night a line drawn toward the north star from the observer's position is approximately a true meridian. The "pointers" of the big dipper are very nearly in line with the north star.

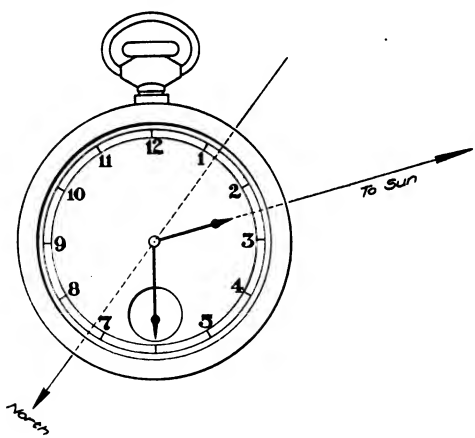

Fig. 14

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CHAPTER IV

Conventional Signs

34. Having learned the means used to represent horizontal distances, elevations, and directions on a map, it is next in order to study the method of representing the military features of cover, obstacles, communications and supply. They include various kinds of growths, water areas, and the works of man. These features are represented by Conventional Signs, in which an effort is usually made to imitate the general appearance of the objects as seen from a high point directly overhead. On account of this similarity of the object to its representation, the student will usually have no trouble in deciding at once the meaning of a new symbol. There is a constant tendency toward simplicity in the character of conventional signs, and very often simply the outline of an object, such as forests, cultivated ground, etc., is indicated with the name of the growth printed within the outline. Such means are especially frequent in rapid sketches, on account of the saving of time thereby secured.

35. "The following abbreviations are authorized for use on field maps and sketches.

Abbreviations other than those given should not be used.

Abbreviations

A.	Arroyo	br.	Bridge
abut.	Abutment	C.	Cape
Ar.	Arch	cem.	Cemetery
b.	Brick	con.	Concrete
B. S.	Blacksmith Shop	cov.	Covered
bot.	Bottom	Cr.	Creek
Br.	Branch	d.	Deep

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cul.	Culvert	P.	Pier
D. S.	Drug Store	pk.	Plank
E.	East	P. O.	Post Office
est.	Estuary	Pt.	Point
f.	Fordable	q. p.	Queen-post
Ft.	Fort	R.	River
G. S.	General Store	R. H.	Roundhouse
gir.	Girder	R. R.	Railroad
G. M.	Grist Mill	S.	South
I.	Iron	s.	Steel
I.	Island	S. H.	Schoolhouse
jc.	Junction	S. M.	Sawmill
k. p.	King-post	Sta.	Station
L.	Lake	st.	Stone
Lat.	Latitude	str.	Stream
Ldg.	Landing	T. G.	Tollgate
L. S. S.	Life-saving Station	Tres.	Trestle
L. H.	Lighthouse	tr.	Truss
Long.	Longitude	W. T.	Water Tank
Mt.	Mountain	W. W.	Water Works
Mts.	Mountains	W.	West
N.	North	w.	Wood*
n. f.	Not fordable	wd.	Wide''

* From F. S. R.

36. Figures 15, 16, 17 and 18 give the conventional signs used on maps published by the United States. These are typical of the signs used on all maps and should be thoroughly understood by all students. The more usual ones such as for trees, fences, streams, bridges, railroads and for all military works, such as demolitions, the different arms of the service, field works, camps, wire entanglements, should be memorized as they are used constantly.

Of these signs the following are specially authorized by F. S. R. for field maps and sketches: Telegraph line on road; Single track electric railroad; single track railroad; double track railroad; improved road; unimproved road; trail; barbed and smooth wire fences; wood, stone and hedge fences.

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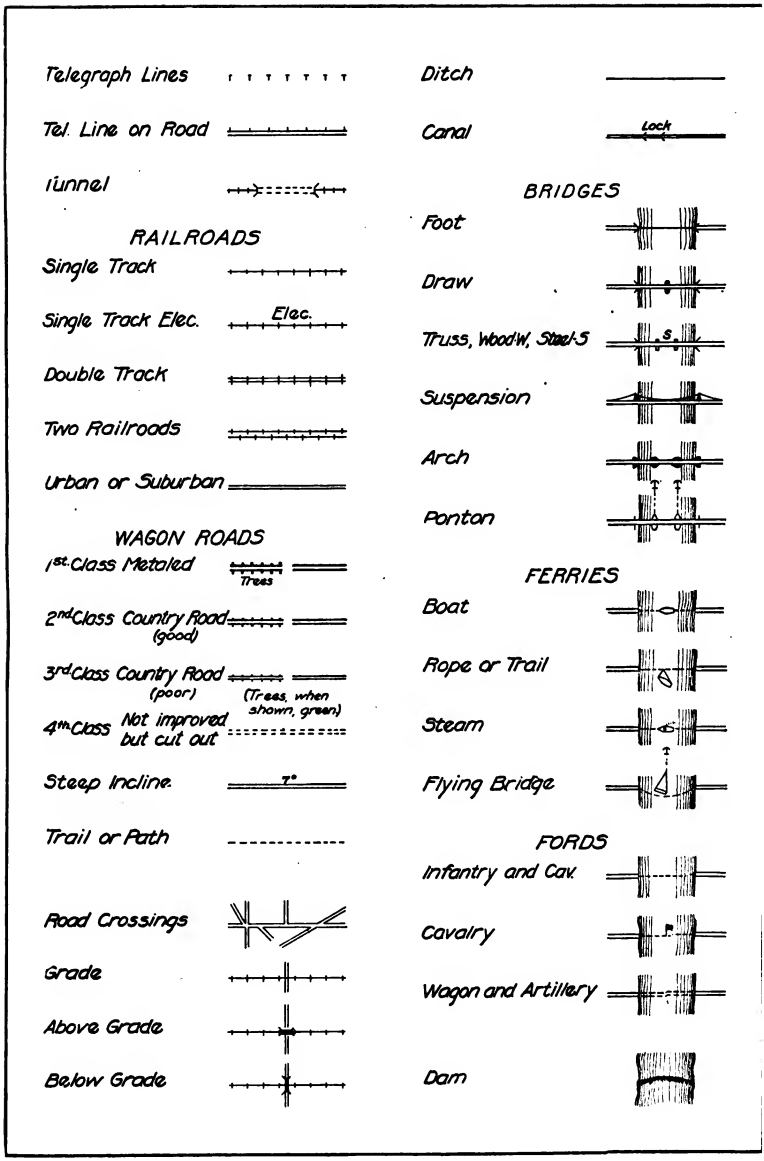

FIG. 15

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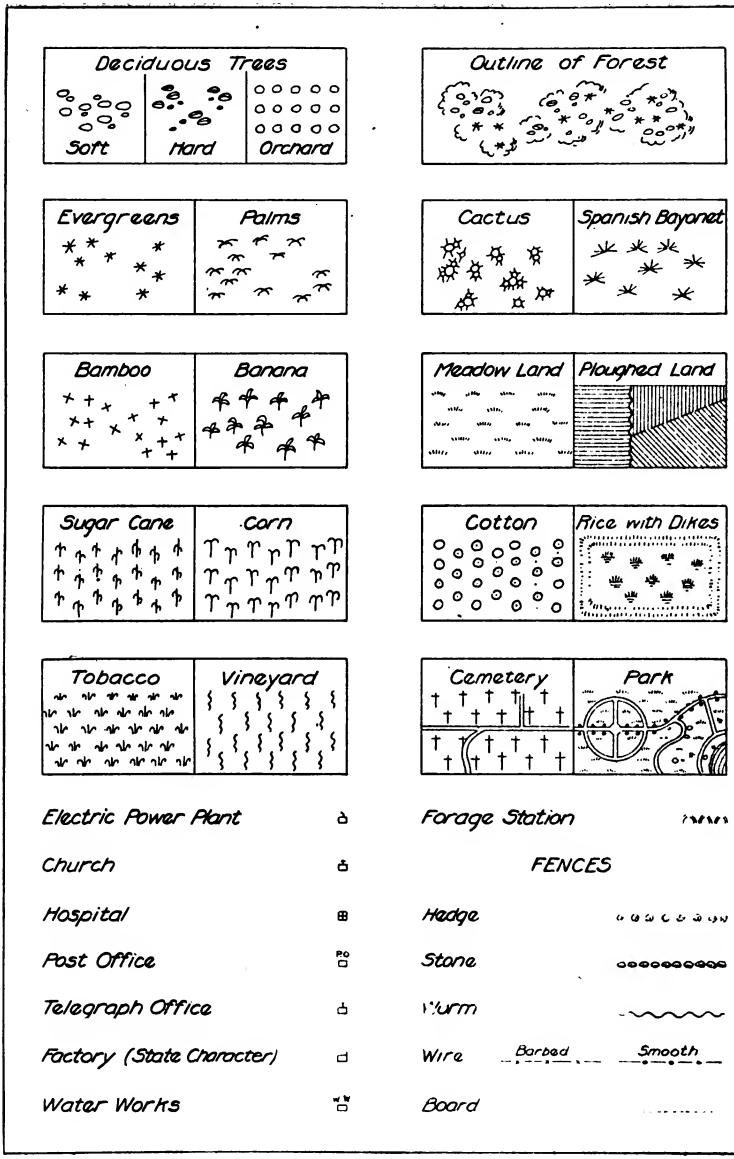

Fig 16

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Depression Contours

Sand, Gravel, Sand Dunes

Levees

Cliffs

Arroyo or Ditch

Railway Embankment

Railway Cutting

City or Village

Capital

County Seat ◎ Village or City •

Buildings

Triangulation Station △

Plane Table Station ⊡

Common Survey Station ⊙

Bench Mark ×BM

Mines and Quarries ⚒

Reservation Boundary ——.——

Streams

Intermittent Streams

Direction of Current

Springs

Lakes and Ponds

Falls

Fresh Marsh

Salt Marsh

Tidal Flats

Dry Lakes

Waterlines

Lighthouse

Beacon Lighted

Light Ship

Life Saving Station L.S.S.

Anchorage

Sunken Rocks

Buoy

Soundings in feet 4 6 10

Fig 17

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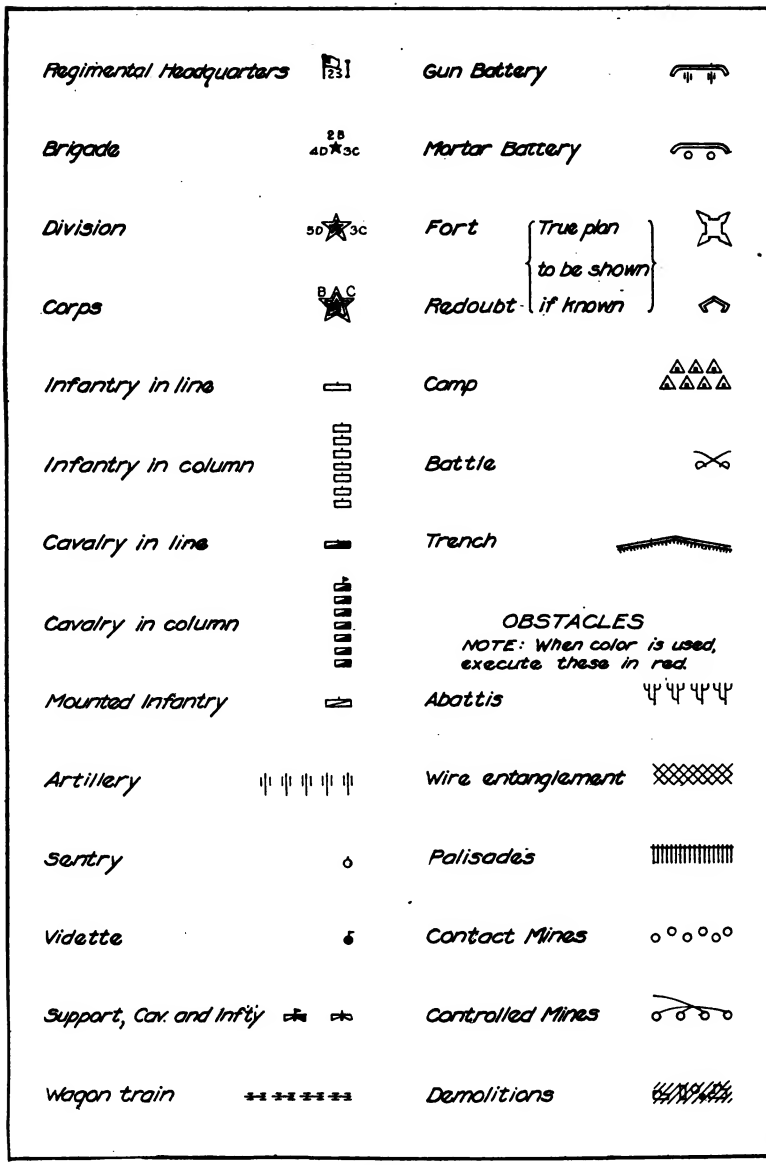

FIG. 18

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37. *Table of English equivalents for words and abbreviations found on German maps.*

WEGE—ROADS

Saumpfad—Bridlepath (in mountains).
Fussweg—Path, Footpath.
Feld-und Waldweg—Field and forest road.
Gen. Verbindungsweg—General connecting road.
Gebesserter Weg—Improved road.
Gebauter Weg—Constructed road.
Chaussee—Highroad (macadam).
Daemme—Dams.

EISENBAHNEN—RAILROADS

Eisenbahn—Railroad.
Strassenbahn—Streèt railroad.

GEWAESSER—STREAMS, Water

Schilf—Reeds.
Bake—Beacon, buoy.
Tonne oder Boje—cask or barrel used for buoy.
Strauchbesen—broom corn.
Duene—sand dune.
Nasse Graeben—wet (damp) ditch.
Strom—Stream.
Bootshafen—Boat-landing.
Eisenbahnbruecke—Railroad Bridge.
Kanal—Canal.
Schleusse—Canal lock.
Trockene Graeben—Dry ditch.
Muehle—Mill.
Wehr—Weir, Dam.
Steinerne Bruecke—Stone Bridge.
Hoelzerne Bruecke—Wooden bridge.
Furt—Ford.
Fluss—Stream, creek, river.
Bach—creek.
Steg—Narrow foot bridge.
Bruecke mit Steinpfeilern—Bridge with stone piers.
Bruecke mit Holzpfeilern—Bridge with wooden piers.
Shiffbruecke—Pontoon bridge.
Wagenfaehre—Wagon ford (or ferry for vehicles).
Kahnfaehre—Ferry (for foot passengers).
Fliegende Faehre—Flying ferry.
Leuchtturm—Lighthouse.
Buhne—Pier (landing stage).

GELAENDEBEDECKUNGEN—FEATURES OF THE TERRAIN

Laubholz—trees with leaves.
Nadelholz—trees with needles.
Gemischtes Holz—trees of both kinds (mixed woods).
Trockene Wiese—Dry Meadow.
Nasse Wiese—Wet Meadow.
Einzelne Baeume—Single trees.
Bruch, Sumpf—Swamp.
Waldboden—Woods.
Heide—Prairie.
Stadt—City.
Flecken—Town.
Dorf—Village.
Gut—Manor, farm.

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Vorwerk—detached farm.
Gehoeft—Farm.
Schloss und Parkanlage—Chateau and park.
Weinberg—Vineyard.
Baumschule—Nursery.
Hopfengarten—Hop Orchard.
Kirche, Kapelle, Kp.—Church, Chapel, Ch.
Forsthaus—Forester's lodge.
Windmuehle—Windmill.
Wassermuehle—Watermill.
Mauer—Wall (stone).
Knick—part wall, part fence.
Zaun—Fence.
Kirchhof—Churchyard, Cemetery.
Friedhof fuer Juden—Jewish Cemetery.
Ausgezeichn. Baum—Lone Tree.
Warte, Thurm—Town.
Bergwerksbetr—Mine.
Ruine—Ruin.
Denkmal—Memorial (statue or anything else).
Steinbruch, Stbr.—Quarry.
Grube—Pit, hole.
Felsen—Rock.
Alte Schanse—Old (abandoned) trench (rifle pit).
Trignometrischer Hoehenpunkt—Triangulation Station.
Reiches und Landes Grenze—Kingdom and state frontier.
Regier.-Bezirk Grenze—Frontier of governmental districts.
Kreis-Grenze—District frontier.

French Military Maps

The French battle maps developed as a result of the European War correspond closely in scale, contour interval and conventional signs to our military maps.

For showing the general features of large maneuver areas, such as lines of communication and enemy positions, they have the 1 to 50,000 map (1.25 inch = 1 mile). This corresponds to our 1 inch to the mile maps such as the progressive map of the Philippines or the Geological Survey map.

The French have also developed a series of battle maps on scales of 1 to 20,000 (3.16 inches = 1 mile), contour interval 10 meters; 1 to 10,000 (6.33 inches = 1 mile), contour interval 5 meters; 1 to 5,000 (12.66 inches = 1 mile), contour interval 5 meters. These correspond closely to our 3 inch, 6 inch and 12 inch maps.

The French 1 to 20,000 battle map is designed especially for the use of the artillery; the 1 to 10,000 map is principally intended for commanders and staffs; the 1 to 5,000 map is designed especially for the infantry in the attack. It is to be noted that modern trench warfare, even over the thoroughly mapped territory of western Europe, requires a more extensive use than ever before of mapping and sketching to show the constantly changing details of the immediate zones of artillery and infantry fire.

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CHAPTER V

Visibility

38. The problem of visibility is based on the relations of contours and map distances previously discussed, and includes such matters as the determination of whether one point can or cannot be see from another; whether a certain line of march is concealed from the enemy; whether a particular area can be seen from a given point; whether slopes are convex, concave or uniform.

On account of the inherent inaccuracy of all maps it is impossible to determine exactly how much ground is visible from any given point over a given obstructing area; that is, if a correct interpretation of the map shows a given point to be just barely visible, then it would be unsafe to say positively that on the ground this point could be seen or could not be seen. It is, however, of great importance for the student to be able to determine whether such and such a point is visible or not, within about one contour interval; or whether a given road is generally visible to a certain scout, etc.

One of the most important uses made of maps by a military commander is in picking out lines of march or positions for troops to occupy in concealment from an enemy's observation stations. In doing this he and his staff officers are continually solving problems of visibility, that is they are approximately determining by inspection of the shape, location and heights of contours on the maps whether certain points can be seen from others shown on the map. It is obvious therefore that every officer and noncommissioned officer should be able to solve these visibility problems

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with reasonable accuracy and rapidity by a simple inspection of the map in order that they may be successful troop leaders.

If you will turn back to figure 6, 7, and 8 and compare carefully the cone, the convex cone and hemisphere with their corresponding contours, you will find that these figures illustrate the most important principles used in solving visibility problems. Take figure 6 for instance, which has contours equally spaced. If you should look from the top of the cone towards the bottom, all parts of it would be visible to you.

If you look down from the top of the concave cone, figure 8, toward the bottom you would see all parts of it even more easily than in the case of the cone where the slope is uniform.

But looking down from the top of the hemisphere you could not see its surface near the lower part on account of the bulging out of the surface as you go down the slope.

Now all hills are divided into three classes, corresponding to these surfaces which we have just examined, and if you should see a hill represented on a map with its top contours far apart, growing gradually closer together toward the bottom, you would know at once that it is a convex hill and a bad place to locate a trench, because there would be dead space below you in which an enemy can approach unseen. A failure to understand this principle has cost many an officer his reputation when he has ordered trenches located high up on a convex hill from which its field of fire was entirely limited towards the front.

If the hill has its top contours close together, gradually growing farther apart as you go down, it is a good place to locate a trench so far as the field of fire is concerned, because no enemy can approach it in concealment.

The visibility of one point A shown on the map, figure 20 from another point B, depends on whether some point between these two projects up above the straight line joining them. The two points A and B may be several miles apart and a number of hills

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may lie between them. The problem of visibility then is to learn how to tell by looking at a map whether any of these hills rise above the straight line joining the two points A and B, whose visibility, one from the other is to be found. The direct line along the surface of the ground between these two points is called the profile between them.

39. *A profile then is the line assumed to be cut from the surface of the earth by an imaginary vertical plane.* A thorough understanding of profiles is essential to the solution of visibility problems.

The representation, to scale, of a profile on paper is also called a profile. In figure 20, *a c′ b″* is the profile of the line from A-C-B. The horizontal scale of this profile is the same as that of the map above. The vertical scale is 1 inch equals 20 feet. It is customary to draw a profile with a greater vertical than horizontal scale, in order that the slopes of hills on the profile may appear more clearly to the eye than otherwise for purposes of comparison. Always note especially the vertical scale in examining any profile. The horizontal scale is usually that of the map from which the profile is taken.

The method of constructing a profile is shown in figure 20 as follows: Lay a piece of ruled writing paper on the map so that its upper edge lies just below the line A-B. Assume that the ruled lines are a contour interval apart=(10 ft.), the 70-ft. contour being the top of the sheet as indicated thereon. At the point on the line A-B where each contour crosses it, draw a perpendicular line down to the ruled line corresponding to the particular elevation of this contour. Draw a smooth curve through these points of intersection and this is the required profile of the line A-B.

With profile or cross section paper, contours can be constructed more rapidly and easily as the contour points can be located by eye, guided by the vertical ruled lines of the profile paper, use being made of the horizontal lines for contours.

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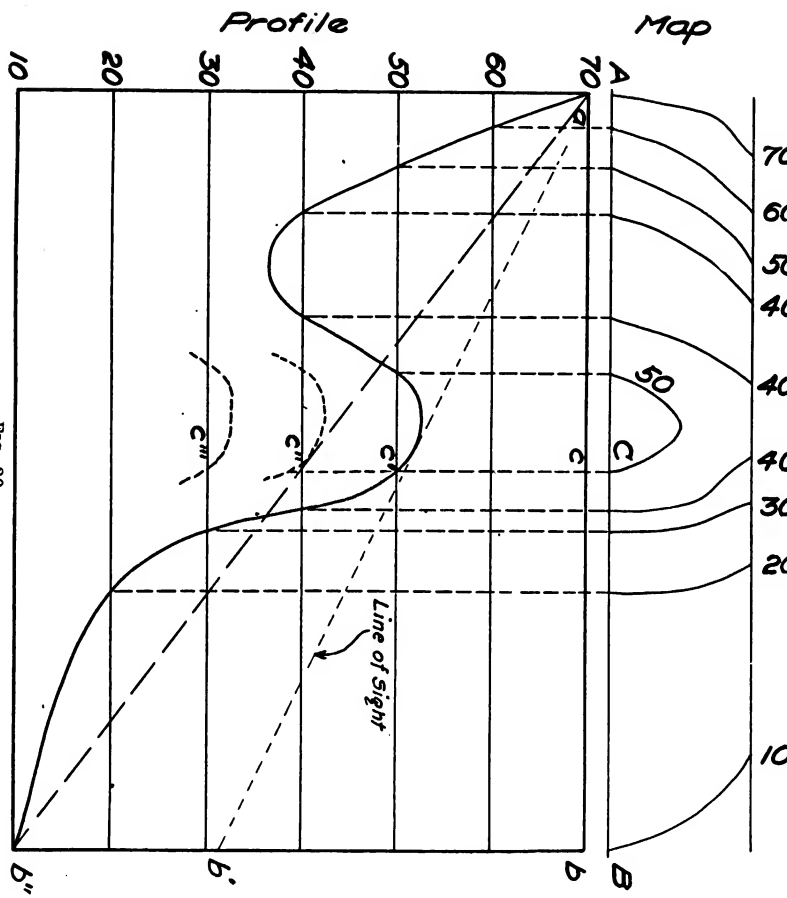

FIG. 20

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Draw a straight line from a to b'' and it is seen that the hill c' extends above it so that B cannot be seen from A.

To find what part of the line A-B is visible from A, draw a line tangent to hill c'. This tangent is a line of sight over hill c'. It is evident that the part from a to c' (A to C on the map) is visible. The part from c' to b'' (C to B on the map) is hidden by the hill c'.

By thus drawing a profile and lines of sight over the various hill tops, the visible and invisible parts of the line from the point of observation may be found. It is only necessary to draw the profile of the point A, the point C, and the point B. Intermediate points on the line need not be considered as they do not affect the solution.

After a little practise of this kind with profiles, the visibility of one point from another can be determined well enough for practical purposes by inspection of the contour spaces on the line joining them on the map.

40. Visibility can also be solved by proportion based on the principle of geometry, that in two right angled triangles having an angle common to both, the altitudes are proportionate to their bases. See figure 20. Remember that it is only when c' projects above the hypotenuse $a\ b''$ of the triangle $a\ b\ b''$ that B is invisible from A.

Problem: Is B visible from A over C? Figure 20. In the triangles $ac\ c''$ and $ab\ b''$ we have the proportion

$a\ c : a\ b :: c\ c'' : b\ b''$ (2)

2 inches : 4 inches :: $c\ c''$: 60 feet, hence

$c\ c''$=30 feet. That is, if C is *30 feet or more* below A, as at c''', B can be seen from A. If C is *less* than 30 feet below A as at c', B is concealed.

From the above we have the general rule: Make a proportion like (2) and if the obstructing point is less than the third term ($c\ c''$) of this equation below A, B cannot be seen. If the ob-

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structing point is below A as much as or more than *c c''*, then B can be seen from A.

You should practice this method by proportion, using a scale of equal parts as an aid until you can make approximate solutions by an examination of the map alone, with the aid of a scale of equal parts to lay off the distances A C and A B. For instance in this case, you can see at a glance at the map that in a horizontal distance of two inches, there is a drop in the line of sight over C of 20 feet, C being on contour 50. In twice this distance, A to B, this line of sight drops *twice* 20 feet, being on contour 30. But B itself is on contour 10, and therefore is below the line of sight and invisible.

Almost all cases can be solved mentally in this way after you learn the principle involved.

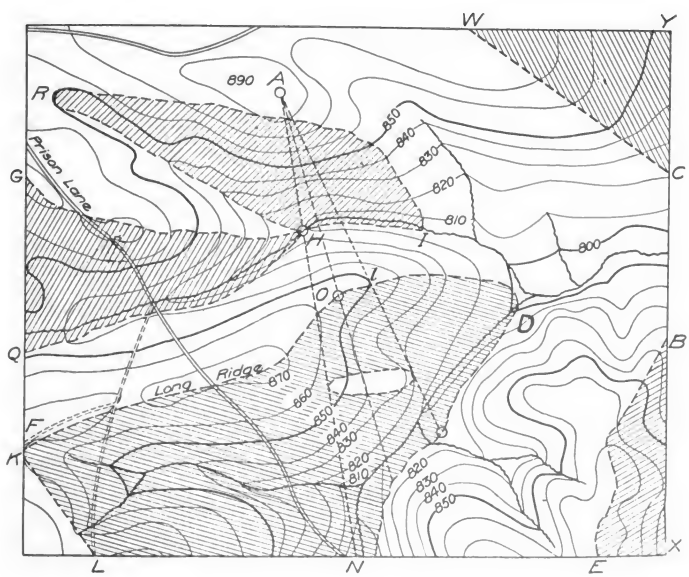

FIG. 21

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The Visibility of Areas

41. After you have learned how to determine the part of a line visible over an obstructing point, you can now find the areas on the map that are visible and those that are invisible from a given point of observation. For most practical purposes these tests can be made from a simple inspection of the map. Occasionally the profile or proportion method may have to be used.

It is of great importance to be able to determine with reasonable accuracy invisible areas from a given point in order to pick out concealed lines of march or positions which cannot be seen by an enemy's observers stationed at the most prominent points in your front. The determinations of visible areas are also very useful in picking positions for our troops from which an enemy's advance can be observed. In figure 21 the shaded areas are invisible and the unshaded areas are visible from the observing point A. Areas CWY, RI and BXE are evident from an inspection of the map. The other areas are found by tests on doubtful points. The lines between visible and invisible areas on ridges GH and Long Ridge are obvious, so that the only tests with profile or proportion are to find two or three points each on lines QH and ND.

On Using Maps in the Field

42. Suppose you are in unknown country and are given a contoured map of a portion of the area your army now occupies, and are informed later you are to make a reconnaissance based on this map. Learn the map as follows:

(1) Observe the scale, see if it is in familiar units and how many inches equal 1 mile, so that you can make rapid mental estimates of the distance between prominent points shown. For purposes of estimation the end joint of the first finger is approximately one inch long. Get this scale relation firmly fixed in mind for the map under consideration.

There is nearly always a tendency to lose yourself in traveling with the aid of a small scale map, by thinking that you have gone

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farther at a given time than you really have. Check up your position frequently by one of the methods given in Par. 31 of locating yourself on the map. Form the habit of observing every road crossing, prominent hill, building and other land marks, to see if they are shown correctly on the map. These observations will help you in learning to use the map. They will train your powers of observation and will increase your ability to estimate distances. They will also, in a short while, tell you whether the map is well made or not.

(2) Learn the contour interval, from the numbering on the contours, or by observing the number of contour intervals between two known elevations, usually marked on hill tops or cross roads. This will give you a clear idea of the relative heights of hills and depressions of streams; and will tell you which are commanding positions, good view points, suitable routes for troops to take in concealment, concealed positions for field guns.

One of the most common mistakes a beginner makes in using a map is in thinking that hills are depressions and ravines ridges, especially where the numbers are not placed frequently on the map.

(3) Observe the position of the true and magnetic meridians, and the number of degrees declination.

Be careful not to orient your map with the north end turned towards the south, an error that can easily be made in an unknown country by reading the wrong end of the magnetic needle.

(4) Pick out the streams on the ground and map and trace them by eye throughout their visible length. This is a necessary step in acquiring a good general knowledge of the ground and map, because the streams form the framework of the area upon which the contours are based. For instance, on the map figure 30, if the streams are first traced as shown, figure 29, it will be possible to imagine the approximate location of the hill tops and

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ridges and a skilled sketcher would be able with this data alone to draw a fairly good map of the area showing the ground forms.

Until you have a clear idea of the location of all stream and ridge lines, you cannot read the map intelligently.

(5) Next pick out the tops of all hills and trace the highest lines of all the ridges. You will be surprised to see how quickly the features of ground represented on the map begin to stand out clear and distinct. You will be assisted in picking out stream lines and watersheds on a properly made map, by noting that the contours heading on the stream lines are very pointed, whereas on watersheds the contours bulge out toward the bottom of hills in rounded curves. This is well shown in figure 30.

(6) Next construct (if not given) a scale of M. D's. for the map and learn the general character of slopes of the ground. See where the flattest and steepest parts occur and the approximately greatest angle of slope, also where troops can maneuver (see table, par. 27).

(7) Pick out all towns and villages, noting their names, sizes, etc.

(8) Trace all roads and railroads and get a good idea which are main roads and which only field tracks.

(9) Next take up the particular points to be investigated and study the map with these in view. For instance, where are good defensive positions, camp sites, lines of observation, good roads with easy grades for the passage of trains, etc.

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PART II

CHAPTER I

Military Sketching

43. *Military Sketches* are rough topographical maps of a limited area, showing in great detail the existing features of military value with sufficient accuracy to meet all military requirements. They are intended to give to military commanders detailed information of the immediate zone of operations, and to furnish the basis for reports of reconnaissances and scouts; for the issue of orders for posting troops in position, for launching an attack, for organizing a march of concentration.

Sketches are of the greatest importance when the operations take place in territory of which there are no maps, but in any case they are essential to amplify and bring up to date the information given by existing maps. Most civil maps are on too small a scale to meet all the tactical requirements; they are also deficient in the details necessary for military purposes, such as new roads, buildings, wire fences, growing crops. *Civil Maps* often show no elevations, or their contour interval may be too large to show important cover, and the contours are usually spaced uniformly from top to bottom of all hills regardless of the actual slope of the ground, thus furnishing little information of the cover afforded or the best line to be held. Military sketches, on the contrary should show concave, convex and uniform slopes true to nature, and all details valuable in military operations.

Details To Be Shown on Military Sketches

44. *All Lines of Communication:* Roads, trails, railroads (with towns to which they lead and railroad stations); rivers, lakes, canals, telegraph and telephone lines.

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All objects giving cover or forming obstacles: Woods, tall growths of grain, swamps, unfordable bodies of water, ravines, rugged cliffs, stone walls, fences, hedges, cuts and fills.

The configuration of the ground: Contours showing all hills in their true location and shape; the character of their slopes and their relative heights; all ravines and slight undulations affording a sheltered line of movement to troops.

All easily distinguished landmarks: Isolated trees of unusual type such as lombardy poplars; houses, especially those of stone and those at cross roads; villages and towns to show the general plan of streets and houses.

All military dispositions: Defensive works (trenches, saps, etc.); bodies of troops drawn to scale.

All forms of constructed obstacles and demolitions, as wire entanglements, mines, etc.

The vulnerable points of lines of communication: Bridges, culverts, locks and dams, ferries and fords, with the character of each.

All stores and supplies for men and animals: Water supply, grazing grounds, storehouses of grain, etc.

A title, giving the locality sketched, the date the sketch is made, the sketcher's name, a scale of yards, the R. F., a scale of M. D.'s and the magnetic meridian.

45. *Scales used on Military Sketches.* The sketch must be large enough to show clearly the smallest details required.

At 6 inches to the mile $\frac{1}{20}$ inch on the map shows 15 yards on the ground, so that on this scale artillery ranges could be accurately plotted. On the other hand sketches must not be too large for convenient handling. The scale must also be of a suitable size

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for easy execution in the field. Consideration of the various requirements have led the War Department to adopt the normal system of scales described in par. 26.

Conventional Signs. The conventional signs used on military sketches may be those prescribed for military maps, par. 36, but the sketcher in making a topographical reconnaissance will rarely have sufficient time to fill his sketch with symbols, and equal clearness, with much greater rapidity of execution will often be secured by printing in small capitals the name of the growth in a given enclosure, as CORN, WHEAT, CULT. (for cultivated). In the same manner, with marginal notes and simple drawings, the character and condition of roads, fences, bridges, fords, buildings, etc., should be described.

For example, a wood king-post bridge forty feet long, twenty feet wide and ten feet above water is quickly and clearly described thus: "w. k. p. $\frac{40\times20}{10}$." Similarly, a stream fifteen feet wide, four feet deep and unfordable, thus: "15 wd.$\times$4'd. n. f."

The sketch should be amplified by a *Reconnaissance Report* of the terrain, where conditions make it necessary, see par. 79. Points from which exceptionally extended views are obtainable should be marked in the margin.

Prominent ridges, commanding positions, church spires, towns, etc., when visible, should have their direction marked by an arrow, with their approximate distance marked on it even when several miles distant, and not on the area sketched.

46. Sketches should be made on *tracing paper* (when copies are desired), in firm pencil lines using a soft black pencil (HB), so that blue prints may be made directly from the sketch without the waste of time and labor of tracing. Since a number of copies of almost every military sketch must be made in the shortest possible time, they should not be finished on heavy drawing paper

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(except in the early practice work or to illustrate a Reconnaissance Report) nor in colors, unless copies of the original are not desired. In combined sketching, the work of all the sketchers should be uniform as to heaviness of lines and size of conventional signs. In case colors are used, the following system should be followed: Yellow for roads; green for trees; blue for water; red for stone structures; brown for contours and wood structures. On the finished sketch, as intended for issue (whether blue print or original drawing), colors may be used with added clearness.

In making a military sketch the important considerations are *clearness, accuracy* sufficient for all military requirements, *simplicity* and the *completed sketch* in the time available. Under service conditions, the *importance of finishing the entire assigned area* in the allotted time can hardly be overestimated; *but in learning to sketch, accuracy and clearness should be the only considerations.* The sketcher should, therefore, in his early sketches, *measure every distance, slope* and *elevation,* after making in each case careful estimates; and he should only begin to depend on his estimates when positive that they are sufficiently accurate.

Only details of military importance should be shown. Objects which are valuable from a tactical standpoint should be constantly kept in mind. It is of far greater importance to show location, shape and character of a wooded area by drawing its outline of conventional signs, within which is written its character, than to carefully fill up an area of incorrect size and shape with symbols for woods. Information of a wide dead space formed by a convex slope in front of a proposed defensive line is more important to the commander than the exact height of the position; therefore care should be used in spacing contours to show the ground as it really exists.

Distances to individual points off the main control lines (traverse or triangulation) should not be in error more than fifteen

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per cent; plainly visible slopes should be correct to within one degree; differences of elevation, within one contour at distances up to five hundred yards from the traverse. It is well for the sketcher to bear in mind that *on the principal control lines accuracy is of first importance,* but in locating any single point from which no other points are determined, its general position relative to the remainder of the sketch is sufficient. Rapidity is gained at the expense of accuracy in some parts of the work, and the difference between a fair and an excellent sketch depends much on the correct choice of the part of the sketch where accuracy is paramount and where it is unimportant.

47. Classification of Military Sketches

Military sketches are classified according to their object or the method of their execution as:

1. *Area Sketches,* which are of four kinds: (a) *Position,* (b) *Outpost,* (c) *Place Sketches,* (d) *Landscape Sketches.*

2. *Road Sketches.*

A *Position Sketch* is one of a military position, camp site, etc., made by a sketcher who has access to all parts of the area to be sketched.

An *Outpost Sketch,* as its name indicates, shows the military features of ground along the friendly outpost line and as far toward the hostile position as may be sketched from the rear of and along the line of observation.

A *Place Sketch* is one of an area, made by a sketcher from one point of observation. Such a sketch may cover ground in front of an outpost line, or it may serve to extend toward the enemy a position or road sketch from the farthest point which can be reached by the sketcher.

A *Landscape Sketch* is a freehand perspective drawing made from some position commanding an extensive view.

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Military sketches are also classified as *individual* or *combined* sketches. An individual sketch is of limited extent, executed by one person. A combined sketch is the result of the simultaneous work of a number of sketchers, so combined as to make a map covering a number of parallel roads (Combined Road Sketch), or an area extending across the front of the command (Combined Position Sketch).

48. Measurements made in military sketching are: (1) Distance, (2) Horizontal Direction, (3) Slope, (4) Elevation.

Methods of Distance Measurement Used in Sketching. The units commonly used are: (1) The sketcher's stride or pace in inches; (2) the distance in inches passed over by the sketcher's horse per minute at a trot, and at a walk; (3) the distance in inches passed over by one revolution of a wheel; (4) 100 yards as estimated by the skilled sketcher.

The Stride.—In all position and outpost sketching, except where the time is too limited, the work is done by the sketcher dismounted making the controlling measurements by pacing. Accurate measurement by pacing depends on the skill of the sketcher in maintaining a uniform length of pace. Good pacing should not be in error by more than 3 per cent on courses averaging from 300 to 800 yards.

49. *To Determine the Length of Stride.*—The sketcher should lay out an accurately measured distance from one-half to two

FIG. 22

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miles long, over ground of varying slopes. He should then pace this course in both directions at least twice, keeping a record of the number of strides with a tally register, Figure 22, held in the left hand. Each time his right foot comes to the ground the left thumb presses the registering lever. This system of keeping the record is the best possible, because the left hand is free to handle the register in the sketching work, and after a very little practice will automatically press the lever as the right foot strikes the ground, which occurs as the left hand reaches the forward point of its swing.

The more nearly automatic the work of pacing and recording strides becomes, the more completely can the sketcher's attention be devoted to observing the details and configuration of the ground and the shape of the contours so essential for good sketching. Also the more automatic the pacing becomes, the more uniform and accurate will be the results. The sketcher should, from the first, remove his attention from the act of recording the strides, because by no other means can he secure uniformity; and in the actual work of sketching his mind is necessarily devoted to other things, such as the observation of the ground, the picking out of critical points, the estimation of elevations and offsets, etc.

Having paced the course several times, the sketcher takes his average number of strides for the course and divides it into the total distance. The quotient is then used as his length of stride in the construction of working scales of strides.

For example, suppose the distance is 2500 yards; and the recorded number of strides, 1560, 1580, 1550, 1570, 1540. The average is 1560.

2500 yards = 90000 inches.

$\frac{90000}{1560} = 57.6$ inches the length of one stride. With this a scale of strides at 6 inches = 1 mile is constructed, see par. 15 (4).

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50. The sketcher now proceeds to make a traverse over the measured course, using this working scale for plotting. On completing this traverse, he measures it on his sketch and should find it to be 2500 yards to scale. If the plotted length is not 2500 yards, the stride used in sketching is not of the same length as that found in pacing the course, and the true length must be determined. Suppose the scaled distance is 2600 yards, then the length of the stride assumed in making the working scale is too long and must be reduced in the proportion $\frac{2500}{2600} \times 57.6 =$ 55.3 inches = the true length of stride, see problem 10, par. 18.

After two or three sketches have been made and tested thus over courses of known length, the stride for all future work will be determined. It should be borne in mind that *uniformity of length of stride and automatic recording* are the important things, because then the parts of the sketch are true relatively though on a slightly larger or smaller scale than intended. However, it is much easier to contour the sketch if the distances plotted are actually on the scale intended, because then the number of contours and their spacing show correctly the true difference of elevation and the true slope between any two points.

51. *Estimation of Distances.*—An essential qualification for a good sketcher is the ability to estimate distances with less than 10 per cent error up to about 600 yards and 15 per cent up to a mile. This can only be acquired by constant practice in making estimates of various distances and then verifying these estimates by measurement or by comparing them with an accurate map.

Get the map of the locality in which you are stationed, take it on the ground and estimate the distances to various well defined points shown, afterward measuring off these distances from the map. Several repetitions of this exercise on different areas will quickly increase your skill in estimating distances.

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Estimates of distance should be made in yards and one hundred yards should be definitely fixed in mind as a reference unit. In all estimation of distance the sketcher should bear in mind the effect of conditions of ground and light on estimates.

Objects appear nearer than they really are:

(1) When the sun is behind the observer and the object is in the bright light.

(2) When seen over a body of water, snow, or level plain.

(3) When down below the observer.

(4) When in high altitudes and very clear atmosphere.

In the above cases add to the normal estimate.

Objects seem further away than they really are:

(1) When up a steep hill from the observer.

(2) In poor light such as fog.

(3) When seen across undulating ground.

In the above cases substract from the normal estimate.

Objects are distinguishable to average eyes at the following distances:

Nine to twelve miles, church spires.

Five to seven miles, windmills.

Two to two and a half miles, chimneys.

Two thousand yards, trunks of large trees.

Six hundred yards, individuals of a column.

Five hundred yards, individual panes of glass in windows.

Four hundred yards, arms and legs of dismounted men.

Each man's eyes are different and the sketcher should learn for himself at what distances objects can be seen by him and their appearance at different ranges, by *noting objects on the ground and scaling their distances from a good map.*

Telegraph and telephone poles are usually set at fixed distances along any one line, so that the sketcher, by pacing one interval (or better, by dividing a known distance by the number of poles contained, to secure their average distances apart), may then make accurate measurements as far as the poles are visible. There

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may be lines of railway telegraph, of different telephone companies, power lines (distinguished by very large insulators) and street railway lines. The average distance between street railway or telephone poles is usually one hundred feet. The interval on each class of lines in the vicinity of his station should be learned by the sketcher. In those parts of the country where the land is divided into sections the *hedges* and *fences* are usually at 220, 440, 880 yards apart.

52. *Estimation of Ground Distances Directly as Spaces on the Sketch.*—When the sketcher has learned to estimate distance with accuracy, he plots these estimates with his scale of yards to locate detail on his sketch. The next step in his training is in learning to estimate the map space corresponding to a given ground distance. This is rapidly acquired by using a scale of hundreds of yards as the unit of plotting. The map distance of 100 yards is .34 inch, at 6 inches to 1 mile, or about $\frac{1}{3}$ inch; 100 yards at 3 inches to 1 mile is about $\frac{1}{6}$ inch. The sketcher should plot, by estimation, 100 yards, then test it with his scale and repeat until he can do it with no appreciable error. It is then easy to plot half miles and miles by estimating $1\frac{1}{2}$, 3, or 6 inches, for representing distant objects not required to be exactly located. The greatest importance of estimating directly the map equivalent of 100 yards, and hence its multiples, is in plotting contours on the sketch directly from their estimated positions on the ground, see par. 62.

Facility is acquired in this estimation of the ground location of contours and their map representation, by taking an accurate map made on the normal scale system, and having estimated the contour's ground position and then having drawn as accurately as possible its map equivalent, compare the result with the same contour on the map. Repeat these steps until you *can trace with accuracy the contour on the ground and plot it as shown on the map.* It will soon be possible to almost imagine you can see the contour following the various curves on the ground.

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CHAPTER II

53. Methods of Sketching

As soon as you have learned your length of stride, have learned to estimate distances, and have made a scale of strides, you are ready to start in with the work of sketching. Figure 45 gives scales of paces at 6 inches to the mile, from which you can if you wish take off the proper scale without the necessity of making one.

Equipment for Position Sketching.—(1) *Sketching Board with attached compass or declinator, supported on an improvised* tripod or camera tripod.

(2) *Loose Ruler,* with scale of hundreds of yards, scale of sketcher's strides, and scale of map distances, figure 24.

All essential sketching equipment is contained in the case furnished organizations by the Engineer Department.

(3) *A Slope or Elevation Instrument:* (a) Service clinometer, figure 40, or (b) Abney clinometer, figure 42; or (c) slope board, figure 28; or (d) Aneroid Barometer figure 43, par. 84, or (e) Hand Level, figure 44.

(4) *Field Glasses.* (Useful for distinguishing distant points.)

(5) *Tally Register,* figure 22.

(6) *Equipped Pencil, Knife and Ruler Holder,* figure 25. It should be carried secured to the sketcher's shirt on his left breast. The knife and ruler may well be fastened to the holder as shown to prevent their being lost.

The Sketching Board should preferably be about 13x14 inches, with a trough compass set in a front edge. There is thus available a drawing surface of about 13x13 inches, which allows two miles

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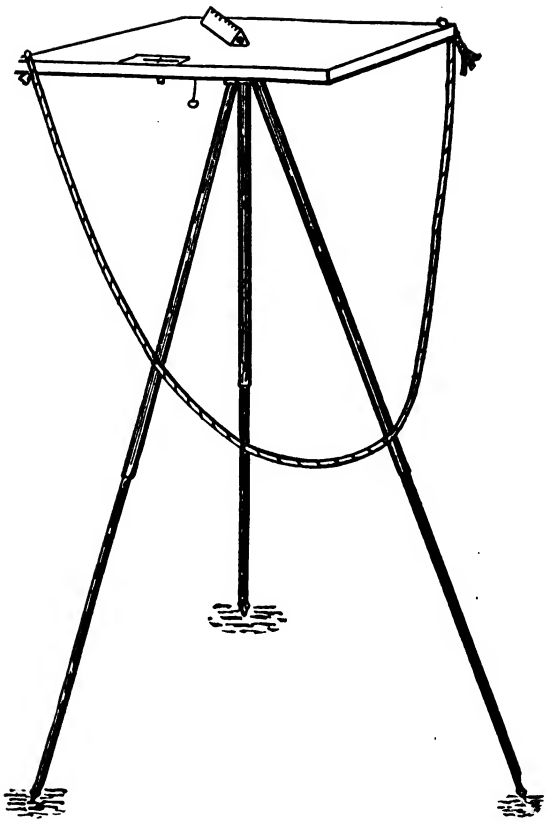

FIG. 23

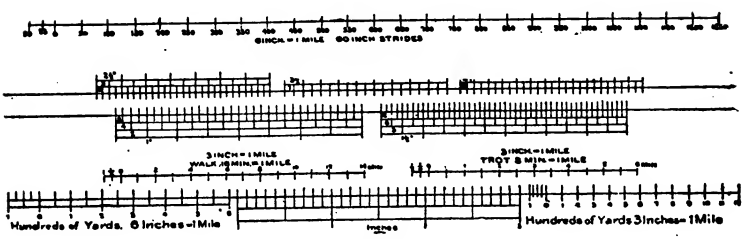

FIG. 24

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of position sketch to be made with enough extra space to secure the paper to the board.

Having a board of this size obviates the necessity of orienting it in any special position to get the area on the sheet. *A tripod* may be quickly made of three sticks about four feet long lashed together a foot from the top. A light folding camera tripod arranged to clamp in any position is very satisfactory. This tripod telescopes from a length of 4 feet to 13 inches and is convenient for both road and position sketches.

An ordinary box compass may be secured to the board instead of the declinator. The compass can be easily attached by screwing it to a piece of cigar box top or a piece of brass, and then screwing this to the back of the board with compass projecting.

The Loose Ruler furnishes a well defined sighting line and carries all the scales required in the work of sketching. It is made of a triangular straight-edge piece of wood, with a hole in each end ⅜ inch diameter x 2 inches deep, filled with lead to give weight to the ruler so that it will remain fixed in position while lines are drawn by its side. On this ruler is pasted a sheet of paper, figure 24, containing scales of hundreds of yards, map distances, and inches. On one blank face the sketcher draws his scale of strides; and on another those of walk and trot of his horse, as shown in the figure. The M. D.'s and scales in figure 24 are reduced one-half. The ruler has a brass ring in one end for attaching to the sketcher's shirt. A coat of shellac makes the paper water-proof. Rulers complete may be purchased from the Secretary, Army Service Schools, Fort Leavenworth, for 35 cents each, and will be found a valuable aid in rapid sketching. For sighting up and down steep slopes a vertical pin stuck in the top of the ruler at each end gives a good line of sight.

It will be of great value to the sketcher to have *one definite place for each article of equipment, and one well fixed method of performing each operation* in sketching so that there may be no

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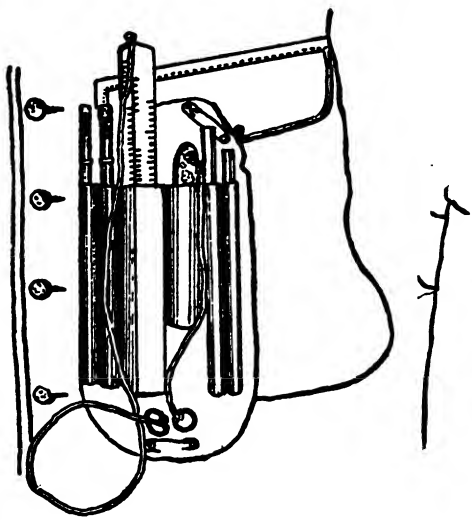

FIG. 25

hesitation in the work. Sketching utensils have a remarkable habit of losing themselves, unless they are tied to something or placed in some particular receptacle after each use. Pencils of different degrees of hardness should be marked clearly so as to avoid delay in taking out the proper one. The points should be protected by rubbed-tipped brass covers.

(7) *A Soft Rubber Eraser* carried attached to a cord around the sketcher's neck is useful.

54. *The Location of Critical Points.* Having learned the uses of military sketches and the details to be represented, it is next in order to take up the methods used for determining the location of the necessary critical points, around which the features themselves are sketched.*

Every critical point desired must be determined: (1) *Horizontally,* that is its horizontal distance and its horizontal angle of

* A critical point is one at which there is an abrupt change of general slope, or an abrupt change of horizontal direction.

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direction (azimuth) from the north-south line must be found, with reference to a starting point, assumed or known.

(2) *Vertically,* either by finding its difference of elevation directly or by determining this difference of elevation from the slope and distance to the desired point with reference to the known point.

A beginner finds it much simpler to become thoroughly familiar with the making of horizontal locations, before attempting the vertical locations, from which contours showing the slope of the ground are determined. For this reason contouring is taken up after the description of plotting in the horizontal details; and the beginner should practice making horizontal traverses, and triangulations, and drawing details such as roads, woods, buildings, streams, before he attempts a contoured sketch.

The Horizontal Location of a Point may be determined either by:

(1) *Traverse,* or
(2) *Intersection,* or
(3) *Resection,* or
(4) *Offset,* or
(5) *By estimation* of distance and measurement, or estimation, of direction.

55. *The location of an unknown point,* as B, with respect to a known point, as A, *by traversing.*

The sketching board, figure 23, is set up at A, figure 26, and levelled as accurately as possible by eye. The board is then *oriented* by rotating it horizontally until the magnetic needle of the attached compass points north. At every station the board must have this same angular position, so that *every line on the sketch will always* be parallel to the corresponding line on the ground. Draw a magnetic meridian on the sheet parallel to the N-S line of the compass. It is well to form the habit of putting an

Capitals as A, B, C, etc., are the points on the ground corresponding to points shown by small letters *a, b, c,* on the sketch.

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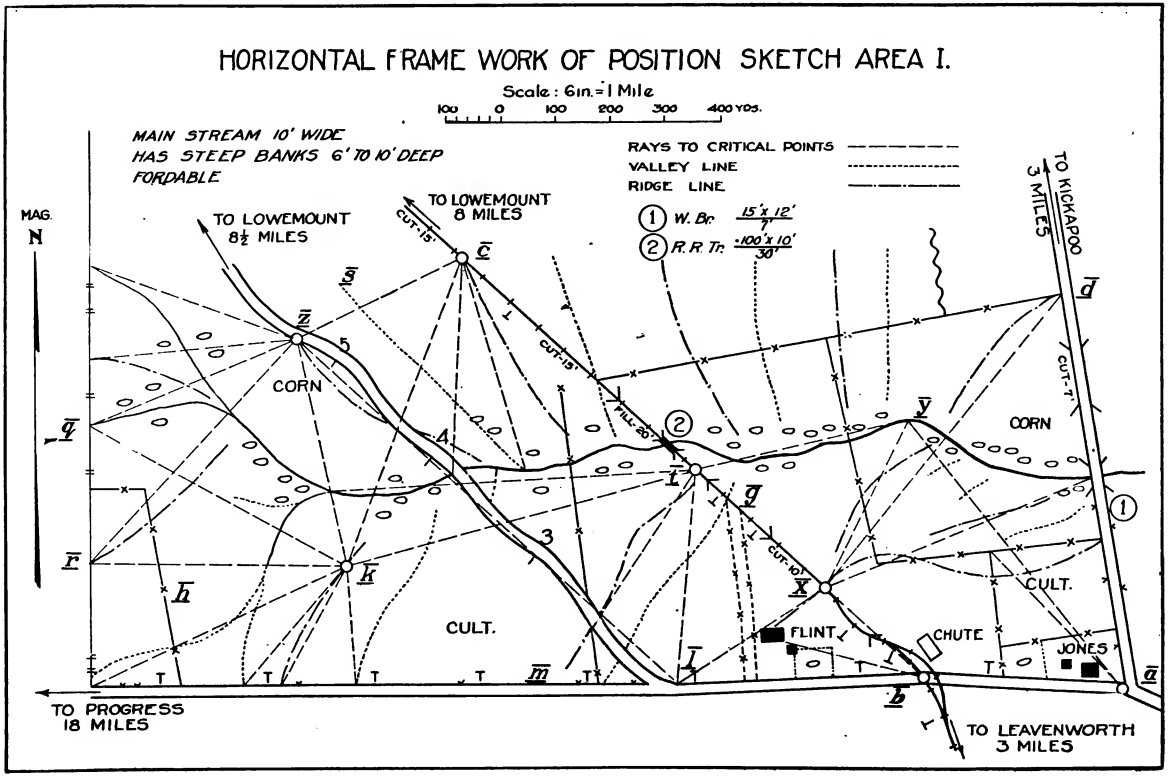
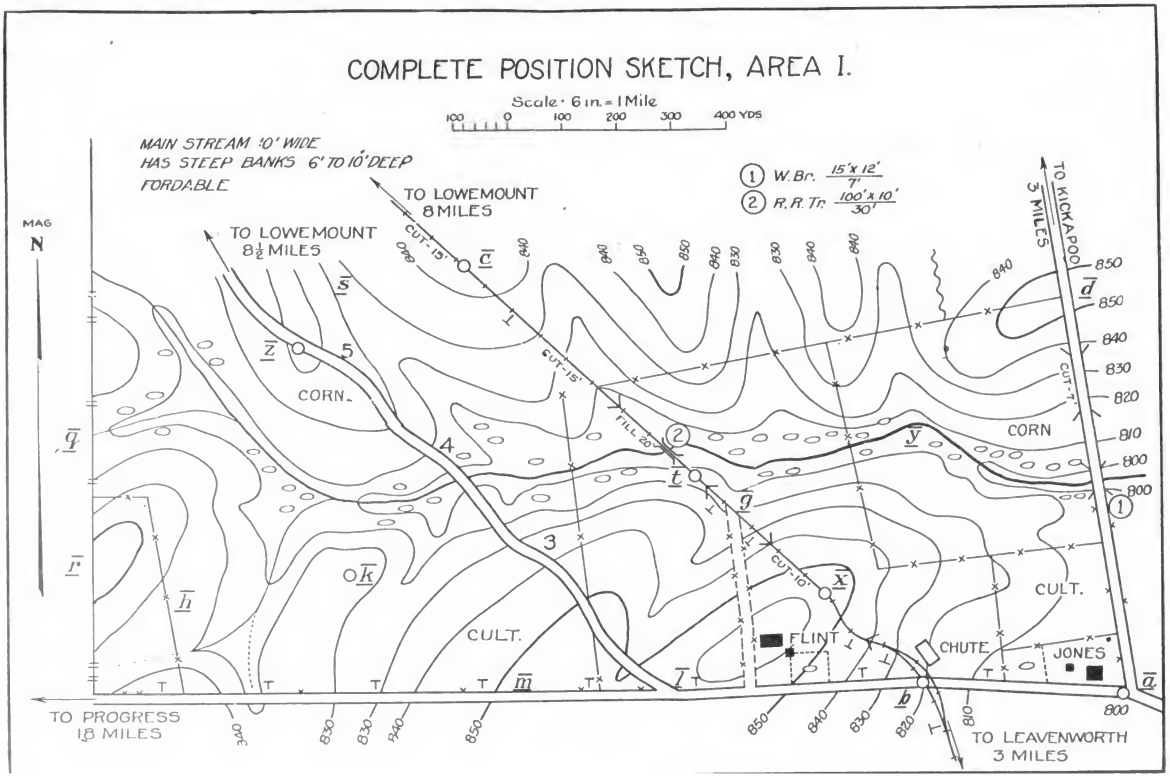

HORIZONTAL FRAME WORK OF POSITION SKETCH AREA I.
Scale : 6in. = 1 Mile
100 0 100 200 300 400 YDS.
MAIN STREAM 10' WIDE
HAS STEEP BANKS 6' TO 10' DEEP
FORDABLE
RAYS TO CRITICAL POINTS
VALLEY LINE
RIDGE LINE
MAG. N
TO LOWEMOUNT 8½ MILES
TO LOWEMOUNT 8 MILES
CUT-15'
1 W. Br. 15' x 12' / 7'
2 R.R. Tr. 100' x 10' / 30'
TO KICKAPOO 3 MILES
CUT-7'
CORN
CUT-15'
FILL-30'
CORN
CULT.
CUT-10'
CULT.
FLINT
CHUTE
JONES
TO PROGRESS 18 MILES
TO LEAVENWORTH 3 MILES

FIG. 26



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edge of the paper parallel to the N-S line so that this edge will be a meridian. Assuming a point *a* on the paper in such a position that the ground to be sketched will fall on the sheet, lay the ruler on the board and point it toward B all the while keeping the edge of the ruler on the point *a*. Draw an indefinite line along the ruler's edge from *a* toward *b*. Now walk to B, counting strides and keeping a record of them with a tally register, par. 49. With the scale of the sketcher's strides on the ruler, lay off the number of strides found from A to B and mark the point *b*. Other points, as C, would be located in the same manner.

56. (2) *The Location of an Unknown Point,* as K, with respect to two known and plotted points, as T and C, figure 26, *by intersection.*

Set up, level, and orient drawing board at T, by laying the ruler along the line *t c* and rotating the board horizontally until the ruler points exactly toward C. (This is called *orientation by back sight,* as opposed to that described at station A, which is *orientation with the needle.)*

Lay the ruler on the board, sight and draw a ray toward K. This ray need not be drawn entirely up to *t,* but only for a short length at the estimated distance to scale of K from T. Now move to C, assumed to be already plotted on the sheet in *c,* and having set up, levelled and oriented by a back sight to T, sight toward K, as done from T. The intersection of these two rays locates K on the sheet at *k*. Having *c* and *k* thus located, they may be used in the same manner for determining other points by intersection. It is seen from the above that a point is located by intersection without the sketcher's going to that point. To locate a point by *resection* the board must be set up on the ground at the point whose position on the sketch is desired.

57. (3) *The Location of a Point by Resection.* 1st Method. Having given a direction line, as *c q* figure 26, on which lies the desired point, and a plotted point, as *k*, outside of that line; to

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determine the position on the sketch of any point on the line C Q, as Z: Set up, and level the board at Z, then orient by laying the ruler on *c q* and rotating the board until the ruler points at C. Clamp the board in this position. Pivot the ruler about a wax headed needle stuck at *k* and sight K. Draw a ray along the ruler and its intersection with the line *c q* locates Z on the sketch at *z*. This method is as accurate as the method of intersection because of the exact orientation secured by back sight on C.

2d Method. Having given two plotted points, as *t* and *c*, fig. 26, to determine the position on the sketch, *k*, of a point K on the ground. Set up, and level the board at K, orienting with the needle. Clamp the board. Pivot the alidade on *t*, at the same time sighting T, and draw a ray along the ruler toward your body at the estimated position of *k*. Similarly, pivot the alidade on *c* sighting C, drawing a ray until it cuts the one from *t* and this point of intersection is the required point *k*. *This method* is available as soon as two visible points are plotted, and *finds very frequent use in sketching in details around a point such as K, which is not to be used to extend the triangulation.* Both of these two methods are of great value in position sketching.

58. (4) *The Location of Points by Offset.* This consists in measuring distances perpendicular to the traverse for locating details. For example, a winding road Z L might be located by sighting from Z toward L and drawing the ray *z l*, figure 26. The distance from Z to L is then measured along the ray (or along the road itself) and critical points 3, 4 and 5 located by offsets perpendicular to the ray. The most general use of this method is in locating details along a traverse where the offsets are made by estimation.

Description of Method of Making Position Sketch, Figures 26 and 27

59. The following steps are taken in making a position sketch showing only horizontal details without contours:

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(1) *Select and Traverse a Base Line.*

(2) Locate a Series of Critical Points over the *Area* by *Intersection.*

(3) Fill in the Detail in the vicinity of the located points.

(4) *Fill in detail around other important points located by Resection.*

(5) *Fill in all other required details by Traverse* to all necessary points not visible from the Intersection or Resection Stations.

The *Base* is a line in the area to be sketched, as centrally located as possible, and from one-fourth to two miles long depending on the size of the area. It should be long enough so that lines drawn from its ends to locate necessary critical points by intersection, will intersect at angles between 30° and 120° to give accurate locations. Its length should generally be not less than one-third as long as the greatest dimension of the area to avoid having to extend small triangles too great a distance from the original base. Often a shorter base can be used if located in the middle of the area than if near one end, because the extension of intersection points would be made on both sides of the base.

The ends of the base should be marked by some well defined objects, such as telegraph poles, trees, corners of buildings, or even temporary poles, branches of trees, weeds, set up by the sketcher so that they may be seen by him from a distance in sighting back on these points. If an object such as a telegraph pole is chosen as an end of the base, so that the board cannot be set up exactly under the point which will later be used to sight back on, the sketcher orients his board near the pole and draws a short ray toward it, pacing and plotting its distance, to scale, measured from the board's location. The pole is thus located accurately on the sheet for back sighting purposes though the board is never set up exactly at that point. This method would also be useful where local attraction is known to exist at the desired station point, as in the vicinity of poles carrying heavy electric currents.

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An extensive view of the area should be possible from the ends and from several intermediate points of the base. If the area is intersected by ridges and valleys, the best base is usually to be found along a central ridge (because from this position the two adjacent valleys are visible as far as the tops of the two ridges beyond. If the ridges are very flat topped and convex in shape, so as to prevent a good view into the two adjoining valleys, it may be advisable to locate the base perpendicular to the axes of the ridges, though the pacing up and down hill is less accurate. A road or railway crossing the area more or less perpendicular to the ridges and valleys, gives a very good base. The accuracy of pacing the base is of great importance, because errors made in this part of the work extend and accumulate over the entire area. To secure this accuracy, the base should, where possible, be generally level and lie over firm soil such as roads, trails, railroads or pasture land.

In figure 26, the broken base A-B-C, along an edge and extending across the middle, is chosen because of the good view obtainable, the good pacing possible along the road and railroad, and the central location afforded. It is started from A because this happens to be the first point of the area reached in going to work; and also because sights to B and D determine two boundaries of the area. The length of this base is such that triangles with suitable angles of intersection are possible. The telegraph poles along B C give good points to resect on.

To Traverse the Base A-B-C

60. Set up and orient at A, as described in par. 55. Assume the corresponding point *a* near the southeast corner of the oriented sheet, because the area to be sketched lies to the north and west of A.

From A, prominent easily distinguished points are sighted, such as hill tops, stream junctions, stream heads, etc., to begin the

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location of these critical points, by intersection.* In figure 26 sight along road A B and A D and toward the stream junction Y, drawing light indefinite lines (rays) with 4 H pencil towards these points. Traverse from A, noting the number of strides recorded on the tally register opposite the house and the wire fence north of road A B but without halting until B is reached.

Procedure at B. Halt, set up, and orient the board by a back sight on A. With scale of strides on ruler, scale off the distance from A to B also from A to house and to wire fence. Now, before the orientation has been disturbed by the work done on the board, pick out with your field glasses the next station, C, an elm tree on top of railway cut, sight and draw a ray in its direction. Next draw in with H (or HB) pencil the road A B, the house at its estimated distance from the road and sketch the wire fence in the direction it was observed to lie. Take a careful sight at the chimney of Flint House, which is a prominent point visible from all parts of the area and will be useful as a point to resect on. Traverse toward C, halting at X. On the top of the bank here, set up, orient by a back sight and take the following observations: Flint chimney; bridge north of A; hill top at road A D north of this bridge (north limit of sketch); directly up the ravine line north of X; to the stream junction just east of the railroad track; to Y. Now sketch the Flint House and barn; the wire fence east of X running toward the north and its branch to the road A D; the stream from Y to road A D and trees along it; the three small ravine lines joining this part of the main stream from the south;

* It is well to have a systematic order of taking the intersection sights from any station, as for instance, from right to left across the front, so that no desired object will be overlooked by a haphazard method. These objects sighted should also be recorded systematically so that the different rays will not be confused when the time comes to finish the intersections. This is best accomplished by placing a serial number exactly on each ray from a station; and on the edge of the sheet, placing a tabulated list of these sights for each station as follows:

From Station A—

Sights:

1. Road A D.
2. Wire fence corner
3. Stream junction.

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telegraph line along the railroad right of way toward B; the orchards at Flint and at A.

Traverse toward C, noting the recorded strides at G and the ridge north of it. Halt and set up at T (south end of bridge). Scale off T, G, etc., from B. Sight on K and along the main stream to the east and west, also up the draw east of C; to intersection of roads A B and L Z also ridge top at M; sketch in the main stream east to Y and the branch ravine lines on this section; the trees and stream banks (shown by hachures or brief statement of condition), and the railroad track back to X. M is at the intersection of the north edge of road A B with the ridge top, and its map representation *m* is at the intersection of *t m* and *a b* prolonged. In the same way, later on, from station K the other critical points (ridges and valleys in this case) on the road are located by drawing rays to intersection with *a b* prolonged. It is well here to call attention to the importance of locating all straight lines in the area such as the boundary fence of this road, wire fences, hedges, straight line of telephone poles, etc., because they furnish a valuable means of locating any points on them by intersection as was done in the location of M from T.

Continue the traverse to C, noting number of strides at wire fence corner without halting. At C halt, set up and draw in detail between C and T, also the wire fence east to D. The east end of this fence was found from X by intersection on the line *a d* from the 1st station, A.

It will be observed that you have now located all the horizontal details east of your Base without traversing any of this area, with a great resultant saving of time. All of this work has been done *by traversing* along the Base and locating the necessary critical points east of it *by intersection.* Sight to K to complete its location, also to the point where road Z L crosses stream, and the ravine line junction with the main stream south of C.

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Resection at Z. It is now necessary to carry the work forward from C, but on hill Z there is no definite point which could be located with certainty from T and C by intersection. You therefore look for something to sight on, so as to establish a direction line on which you can place yourself after reaching hill Z. You observe that you can look exactly up a small ravine toward a tree at Q, so draw a ray in this direction. (A well defined fence corner, bush, etc., would be equally as satisfactory as the ravine to sight on.) Move at once to the top of hill Z and place yourself on the direction line from C, at the most convenient point of the hill for observing the ground (on road Z L). Set up and locate your position by resection on K, and sight the stream junction toward K, also the draw S by estimating its number of yards from Z. Sight along the general direction of road L Z. You observe that a hedge fence extends along the western boundary through Q. You have not located this hedge, but observe that you will be able to do so by intersection from Z and K on two of its points, Q and R. Therefore, sight from Z at these two points on the hedge, then move to K and complete their location. Draw in the hedge R Q, thus locating all the critical points sighted on this line from E. From K locate the critical points on road A B as described above. Draw in all the water course and water shed lines west of the railroad, for which sufficient critical points are now known; also the other details such as roads, trees, houses, wire fences, etc.

It will be observed that the horizontal details of this sketch have been put in by use of the methods of *traversing, offsets* (along the base), *intersection (d, m, k, q, etc.),* and *resection* (z). S was located by *estimation,* since it was only about 200 yards from Z. A small amount of estimating has been done in getting the directions of ravines and of water sheds of ridges, between the two or more points located on them. Gradually you can increase the amount of freehand sketching based on estimation as you acquire skill from practice. The portions of the area located

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by resection, intersection or traverse will vary in amount for each particular sketch, depending on the nature of the ground, the amount of woods, etc., preventing good views.

It is evident that the work from a carefully paced base over fairly level ground is more accurate than if traverses were run all over the rough and steep parts of the area. Therefore, as much of the work is done by intersection and resection as possible, traversing (except along the base) being done only where desired critical points are hidden by woods, etc.

You will also observe that *all sketching of details has been done toward the rear*—that is, from the last located point back to others previously determined. This is a vital principle in all this work, that *no sketching should be done in front of the last located point.* (Except that local details may well be put in by estimation for 50 to 100 yards forward from each station.) There is with beginners a strong tendency to do this, especially in drawing contours, but such work will usually be incorrect and have to be erased, causing a waste of time and great confusion to the sketcher.

Vertical Measurements—Contours

61. As soon as you have finished locating horizontal details on several sketches, so that you can do this work readily, the next step in making a complete position sketch is to learn how to put in the contours to show hill forms and slopes. Before this is practicable you must learn to read vertical angles with one of the vertical angle reading devices, such as the slope board, figure 28, service clinometer, figure 40, or Abney clinometer, figure 42.

We will assume that you have only a slope board to start with.

A slope board, figure 28, is a device consisting of a plumb line and graduated arc placed on a drawing board for measuring angles of slope. When a point is sighted along the edge AB, the plumb line makes the same angle with the perpendicular DC, that AB makes with the horizontal, and, therefore, gives the angle of

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slope. Such a slope board may be constructed as follows: Lay off a perpendicular to AB along the line CD, and on it take DE = 5.73 inches. Describe a semi-circle with this radius and lay off from E toward A and B successive distances of one-tenth inch along the arc. These are degrees from CD, because one degree in a circle of 5.73 inch radius gives a chord of one-tenth inch. These degree marks are extended to the edge of the drawing board with a ruler, as shown in the figure. To read slopes, attach a plumb line at D, sight the object along AB, holding the front of the board vertical. When the plumb line comes to rest press the string against the edge of the board with the finger and read the angle marked. The result should be correct within one-half degree on still days; but if the wind is blowing, good readings

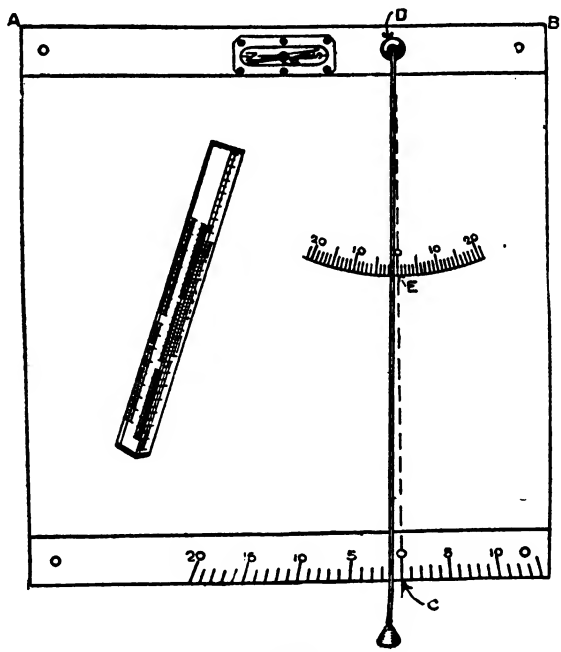

FIG. 28

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cannot be secured. The slope board is easily made and is valuable for a sketcher who has no good clinometer.

With a slope board, estimates can be checked until the different slopes are learned. It is also useful for reading slopes of hills in profile, that is from a position off the hill from which a good view along the water shed is possible. To do this hold the board parallel to the front of your body, with the lower edge parallel to the slope of the hill, at the same time noting the angle marked by the plumb line. The Abney clinometer can be used in the same way. This method is particularly useful in reading the slopes of hills so convex that a view directly down the water shed can not be obtained. If you wish to use the service clinometer or Abney clinometer for reading slopes, or the barometer for differences of elevation, see appendix for directions as to use and adjustment of these instruments.

The Estimation of Slopes

62. In addition to being able to read slopes or differences of elevation with an instrument, it will also be necessary for you to learn to estimate slopes and differences of elevation accurately to become a skillful sketcher.

The ability to estimate correctly the general slope between two points is important for accurate contouring. The sketcher should have a carefully adjusted clinometer or a slope board, and make a series of estimates over various kinds of ground, verifying each estimate with a careful clinometer reading. In reading a slope with a clinometer, the sketcher should sight some *definite object*, as a tree, at a point above the ground equal to the height of his eye, to get a line parallel to the surface of the ground. Some sketchers in reading an important slope take a prone position and sight just off the ground at the desired point, thus getting more accurately the height from the ground of the point to be sighted. The prone position also gives a steadier position for the clinometer, unless it can be rested against a post or tree.

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In determining slopes by clinometer reading or estimation the habit should be formed of considering the slope from one definite point to another on the ground, and not simply from one locality to another. The estimate of slopes should be checked with careful readings. The slope board should be used for this purpose only on still days, when good readings are possible.

Both horizontal and vertical angles may be estimated with considerable accuracy by determining the number of degrees subtended by the sketcher's hand or finger held at arm's length from the eye. The average angle thus subtended by the hand is about $8\frac{1}{2}°$, but its exact value must be found by each sketcher for himself. The arm is extended full length in prolongation of the shoulder (rather than to the front so that the distance from eye to hand will be constant), palm up for horizontal and to the front for vertical angles, fingers perpendicular to the palm. The sketcher takes position about 20 or 30 feet from one of the walls of the room and locates the point on the floor, above which his eye comes, when looking past his shoulder and hand held as described. He notes on a rod, or other foot and tenths graduation, against the wall the points visible past the middle joints of the first and fourth fingers. A box compass is placed above the point on the floor over which the eye was located, and the angle between the two marked points is read. Similarly, the angle for one, two and three finger widths may be determined. Horizontal angles can be quite closely estimated by laying off successive "hands" between the two points considered, being careful to rotate the body so that the arm will always be in the extension of the shoulder.

Instead of thus using the hand at arm's length, the sketcher may similarly determine the angle subtended by one, two inches, etc., held at the fixed distance of 28.6 inches from the eye. Mark on a string a 28.6 inch length; hold the sketching ruler at one end and the eye at the other end of the string; then one inch on the ruler thus held subtends an angle of 2°.

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To estimate vertical angles, the sketcher must learn to *trace a contour*—that is, to be able to place the hand or ruler in the horizontal plane of the eye. To do this, mark a number of points around the room at the exact height of the eye. Practice sweeping an arc with the arm at such height that the sight over the finger passes through the marked points. Note carefully the position of the arm during these exercises, and in a short time a very accurate horizontal can be thus marked. This practice is of assistance in noting the position of contours, in determining a reference plane from which to estimate vertical angles and differences of elevations, and in marking points of equal elevation forward on a traverse.

After considerable practice it will be possible for the sketcher to estimate slopes with sufficient accuracy by simple observation of their general appearance. Similarly the sketcher soon learns *to trace the contour on which he is standing,* and the position of those above and below it by noting the slope of the ground at various critical points. For example, having estimated the location of the 840 contour from K (Figure 27), the 850, 830, etc., are drawn in by eye to show a 2½ degree slope at *z*, at 1½ degree at *h*, etc., with proper attention to the character of the neighboring ground.

If the sketcher can secure an accurate map made on the normal scale system it will increase his ability in estimating slopes as well as map distances corresponding thereto, to go into the field and *make careful estimates and check them from the map.*

A mistake often made by sketchers is to estimate slopes, distances and elevations, before they have a definite idea of these units. Such estimates are but guesses and are fatal to good sketching. It is equally incorrect to suppose that all proper estimates are only guesses, because it has been repeatedly demonstrated that rapid sketches, which equal instrumental surveys in the graphic representation of ground, can be made without slope or elevation measuring instruments.

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The Estimation of Differences of Elevation

63. *The ability to estimate accurately differences of elevation* is of the greatest value in rapid contouring, because these direct estimates of elevation are found to be more nearly correct than the elevations determined by estimation of slope and distance. Elevations found from slope and distance are affected by errors in both slope and distance. If the slope is correct, but the distance too great, then the map distance (M. D.) for the slope is contained too many times in the plotted distance, giving too great an elevation.

Method of Making Estimates of Elevations.—Having first learned to determine a horizontal plane (using hand level, clinometer or extended arm) the elevation of the unknown point above or below this plane is estimated by comparison with the heights of objects in the vicinity, such as telegraph and telephone poles, trees, horizontal lines on buildings and bridges (copings, window sills, etc.). The height of main line telephone or telegraph poles is usually 25 to 32 feet; of street railway poles about 25 feet; trees in a full grown orchard 15 to 20 feet; full grown oak trees 40 to 75 feet; the height of an ordinary story of a brick house (window sill to window sill) 12 feet. The sketcher should learn the height of such familiar objects in the vicinity of his station. In estimating the height of any object to be used as a reference, it is well to *keep in mind a well known value such as 10 feet* and imagine this applied successively to the object.

Suppose the sketcher is standing on a hill, looking in the direction of the traverse, across a valley toward another hill. He makes a careful estimate of the point (or locates it through his hand level) at which a horizontal plane strikes the hill across the valley. Then by observing the position of the bottom of the valley with reference to this plane, the sketcher estimates the difference of elevation as so many telegraph poles, etc., below the plane. The result should never be out more than one-half contour interval.

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The best method of checking these estimates, is to *consult an accurate map* after making the estimate and see the difference in elevation shown.

By *carrying forward with long sights* (using hand level or clinometer at zero), points of equal elevation along a traverse, elevations throughout a day's road sketch can be obtained with sufficient accuracy. Another assistance in carrying elevations and in securing correct contouring, is the *uniform slope of streams.* The surface of a large river is practically horizontal so far as the requirements of a day's sketch are concerned. The Missouri river for instance, has a surface slope of only 6 inches per mile, or only 7½ feet in 15 miles of length. Hence wherever the sketch approaches the river, there is furnished a reference for elevations. The same principle is true of smaller streams, which usually, over considerable length, have a practically uniform rise, as 10, 20, etc. feet per mile. Having determined this rise, the elevation of each crossing of the stream is thus known. Often in sedimentary formations, an *outcrop of rock* will always occur at the same elevation. The sketcher must learn to observe all topographical features and make use of them in his estimates.

Contouring the Position Sketch

64. Having completed the location of the horizontal details of the area, as described in par. 59, figure 26, start in again at A and find the vertical locations—that is elevations, slopes and contours necessary, correctly to represent the shape of the ground.

In the sketch you have already located the horizontal positions of all critical points such as stream lines, draws (water flow lines), hill tops, railroads, roads and buildings.

Methods in detail of finding the elevation of an unknown point D *from a known point* A, figure 27, *and the location of contours on this line.*

Measure the slope from A to D with clinometer, or slope board, and apply the M. D. for this slope successively along the plotted

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length. The number of times the M. D. is applied, multiplied by the contour interval (V. I.) equals the difference of elevation between A and D. Suppose A, figure 27, is at elevation 800; distance *a* to *d* as plotted 2.5 inches; V. I. = 10 feet; slope from A to d = $+1\frac{1}{2}°$. The M. D. for $1\frac{1}{2}°$ is found to be contained $5\frac{3}{4}$ times between *a* and *d*; $5\frac{3}{4} \times 10 = 57.5$ feet. D is therefore at elevation $800 + 57.5 = 857.5$. Now looking at the ground along A D, you find it to be a slightly concave (hollowed out) slope north of the bridge and steeper near the top. There are to be placed in the space *a d* contours 800 (at *a*), 810, 820, etc. to 850; they would be spaced close together at the top and farther apart towards the bottom in order to give a true representation of the slope. South of the bridge (1) the ground is level and consequently no contours appear here.

In rare cases only do the slopes of hills change so suddenly at any one point that the actual condition of slope can be shown by a mechanically exact interpolation of contours by the application of the scale of M. D.'s. above or below this point of change. In reality *there is always more or less uncertainty as to the exact point at which the change takes place.* Moreover, it is exceptional to find ground sloping exactly uniformly. *The usual case is either a convex or concave slope, changing so gradually from point to point that the observer can not pick out the exact points of change, much less be able to mechanically show these points by contours. He can however represent by contours the general character of the slope accurately by contours properly spaced.*

In the older textbooks a laborious method of contouring was prescribed in which the sketcher would pace along a slope to each point of change and plot the contours on these portions. This method is impossible for rapid sketching on account of its slowness and is moreover inaccurate on account of the accumulation of errors due to the frequent short readings to unimportant points.

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In military sketching the essential feature sought in contouring is to convey to the reader of the sketch a correct representation of the ground as it appeared to the eye of the sketcher. The sketcher can only give this information by determining the difference of elevation between two definite points, at the top and bottom of the line, and then, knowing the number of contours required, *spacing them to show the variations of slope as they appear to him.* For this reason great stress has been laid on the necessity of acquiring by diligent practice the ability to estimate the map distance corresponding to each degree of slope usually met with.

2d Method—Measure the difference of elevation directly with the barometer, and space the contours required by this determined difference of elevation to show the actual slope of the ground.

Method of Contouring After Acquiring Skill in Estimating Distances, Elevations and Slopes.

(a) *Estimate the difference of elevation* between A and D, Fig. 27, and, *space the contours by eye.* Or the number of contour intervals between A and D may be estimated. In this case the number of contours, including the top and bottom ones, is one greater than the number of contour intervals.

(b) *When a Generally Uniform Slope Extends to the Limits of the Sketch.*—(1) Read the slope with clinometer or slope board and, with a scale of M. D.'s locate contours to the limits of the sketch, without determining the elevation of any point on the line other than the one known.

(2) *After Skill in Estimating is Acquired,* estimate the slope and plot the contours with scale of M. D.'s.

(3) *After skill in plotting by estimation of map distances corresponding to different slopes is acquired,* estimate the slope and space the contours by estimation.

Procedure at B. Next move to B and read the angle to A (—1°), and applying the M. D. scale, you find two contour intervals between A and B the ground is quite steep near B and

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flat near A. You therefore space the contours as shown in the figure. To verify your idea of how close together to space the 810 and 820 contours, read the slope from B to the foot of the hill. You find it to be (—3°) by applying the M. D. scale; this agrees with the spacing already estimated. While at B note the general slope of the road to the west for use in spacing contours along it later.

Next move to X, set up and read the slope to B (—3°), to Y (—3°), to G (—3°). Application of the scale of M. D., shows that B (820) is 3¾ intervals below X. Hence X is at elevation 857. The slope from X to B is practically uniform and the contours are spaced as shown. Applying the M. D. scale, you find 5½ intervals from *x* to *y*. This is a gently convex hill and the contours are drawn as shown. Since X is 7 feet above the 850 contour, this is placed nearly one M. D. distant from *x;* and for a similar reason the 810 contour falls a short distance south of the stream. Join up the contours between the line *x y* and *x b a,* with due regard to intermediate slopes of the ground. Also, having determined the elevation of Y (805), you are able to draw in the contours on the ridge *y d* by examining its slope through your field glasses. Extend these contours to join those already located south of *d,* keeping in mind the variation of the ground and remembering the small map distance corresponding to small inequalities noted.

Estimation. Instead of reading the slope to the top of Flint Hill you observe that it is only 5 or 6 feet higher than X, and hence only one contour (860) goes in; this falls about 50 yards from X, and is drawn in by eye as shown. You also draw in those required between the 850 contour and B along the road.

Now move to T and stop a moment to read the slope up ravine G, without setting up the Board; likewise at the ridge just north of it. Continue to T, set up the Board here and put in contours between X and ravine G, and on ridge M.

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Read the slope from T to X and find the elevation of T as heretofore described for B and X. From T read the slopes to ridge and valley points on the fence running east to D, and draw in the contours down to the main stream.

Proceed to C; read the vertical angle to X, to K and to stream junctions south of C, locating contours as already explained. Continue over the entire area, always remembering to locate contours in rear of the last known point, and not to leave a station until all the details up to that point are drawn in.

65. *Locating Horizontal Details and Contours Simultaneously:* Having finished locating the contours over your first area, go back again to A and carry on both horizontal and vertical determinations together. This can now be readily done simultaneously on the area you have studied by the two separate operations. For example, at A, set up, orient with the needle, draw a meridian, sight D, B, Y, and fence corner; read vertical angle to D draw in road A D. Move to B, set up, orient by back sight on A, plot *b,* house and wire fence; sight C; draw in road A B (note slight curve), cattle chute and switch; sight Flint House chimney. Now read the vertical angle to A and contour *a b,* and so on continue the work, being careful to follow a regular order in the different steps. It is well to keep in mind, however, that there are really two independent sets of determinations being made at each station, one horizontal the other vertical, as this helps to systematize the work.

As you acquire skill in sketching, in estimating and tracing contours, you will constantly require fewer and fewer controlling located points, such as B, X, Y, etc., with a corresponding gain of speed and accuracy of representation.

66. *The development of a position sketch* is clearly shown in figures 29-30. Figure 29 A shows the stream and water-flow lines and the locations and elevations of the critical points which must be secured as a basis for putting in contours. You

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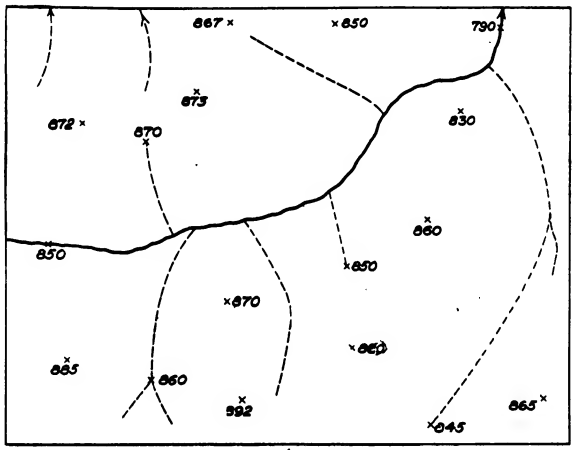
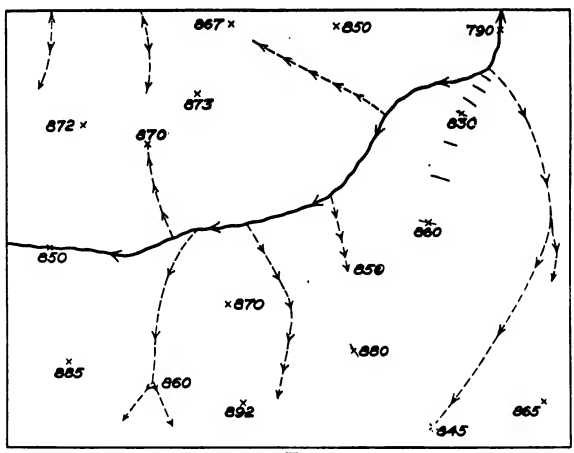


A

Arrow heads show direction of water flow.



B

Arrow heads (except those appearing also on A) are points where contours cross streams or dry runs.

FIG. 29

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will observe how few these points are and yet what a lot of information they give because they are taken at just the right points.

The first thing to be located would naturally be the main stream 850-790, and since only two points were taken on it you assume that its slopes are uniform unless informed otherwise. Knowing this you at once put in the contour crossings as shown on figure B. These crossings at once tell you the elevation of the lower end of the branches running into this stream.

The elevation of the head of each branch is also taken and then you can put in the contour crossing points on these. On the ridges, only enough points are taken to show decided changes of slope and it will be noticed that on ridge 880-860-830 there are three different slopes, very flat at the top, steeper near the middle and steepest at the bottom.

Even if you had never seen a piece of ground and should be given such a set of critical points, you see how easy it would be to contour the map with considerable accuracy, assuming ordinary conditions of slopes.

There is no practice more valuable than in contouring sheets prepared as those are in the figures. The Service Schools will furnish them on request.

Execution of Outpost Sketches

67. *The Making of an Outpost Sketch* differs from that of a position sketch in nothing except that in the former the sketcher cannot advance beyond the line of observation, but must show the ground from one-half to two miles in front of this line toward the enemy. Consequently, he will be limited to locations by traverse along the base and intersections from stations on the base to determine critical points over the area out in front. The method of resection is not usually applicable because this requires that the sketcher go to the point located. *The Base* might, however, be located *some distance in rear of the outpost line* (if the sketch were being made under fire of the enemy, to avoid

Figures 29 and 30 are from Bond's *Engineer in War*.

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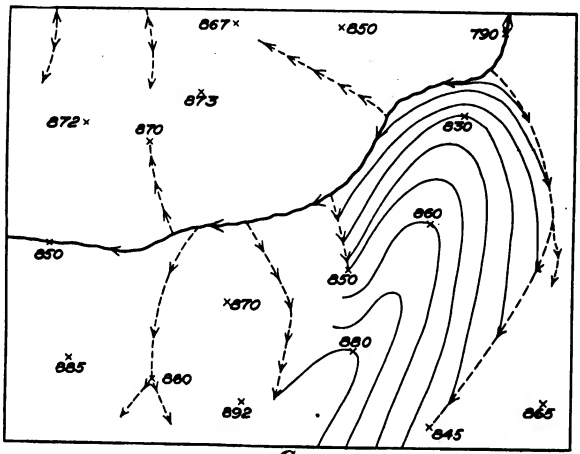
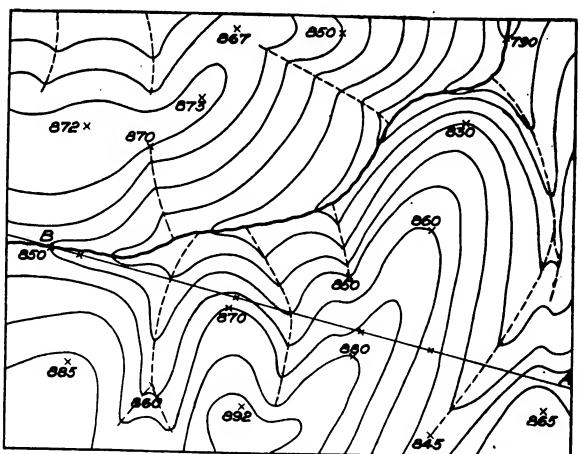


C



D

FIG. 30

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exposure in traversing along the line of observation); and from this retired base critical points could be located on the line of observation by intersection or resection. The sketcher would then approach these located points by creeping up from the rear, orient his board flat on the ground and sight necessary critical points over the foreground. The information to be represented on the outpost sketch is the same as is shown on a position sketch and on the same scale.

There will often be portions of the base from which good views to the front are not possible. It is therefore necessary to study the ground most carefully from each base station, in order that critical points may be selected which can be seen from at least one other point located along the base, so as to give good intersection angles. For the critical points only a short distance in front, observations must be taken from points correspondingly near each other along the base. To locate critical points far to the front, the extreme ends of the base would probably be used as stations from which to intersect.

It will often be impossible to see more than a small part of one hill beyond another, or the lower part of a small ravine may be seen, of which the upper part lies beyond a hill. If, as is often the case, a good estimate can be made of the nature of the hidden area, judging from the visible parts, then the concealed portions should be drawn in broken lines to indicate the method of location used.

Field Glasses are of great assistance in this work in picking out definite objects to intersect on, and in discovering folds of the ground not visible to the naked eye. If two ridges lie generally parallel to the front and at some distance from the base, it will often be possible to discover the further one only by the line of different light made by the nearer one against the side slope.

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Execution of Place Sketches

68. *A Place Sketch* is made under the supposition that the sketcher is limited to a single point of observation overlooking the area to be sketched. The details to be shown are the same as on a position or outpost sketch. The scale used is ordinarily 6 inches to the mile, but if it is made to extend a sketch further toward the enemy than can be reached by the sketcher the scale of this sketch is used.

The sketcher must have acquired considerable skill in sketching and in making estimates of distances, slopes and elevations before he can successfully make a place sketch. The methods of work heretofore described for position are followed except that all control points are located by determining distance with range finder (or by estimation), elevations with clinometer (or by estimation), horizontal angles of direction, with plane table or compass. First locate stream lines, next roads, then hill tops, and finally contours and minor details.

The place sketch is made under the same conditions as a perspective sketch, but has the advantage that it represents truly to scale the features of the ground in their relation to each other as estimated by the sketcher, and to be interpreted need not be examined from the point occupied by the sketcher. The sketcher's estimates may be in error, but his sketch will show the ground according to these estimates. A perspective drawing, on the contrary, furnishes no means of determining relations of distance, slope and elevation. They are valuable, however, for persons ignorant of map reading, or to illustrate descriptions of military positions for non-military readers. All staff officers and especially artillery reconnaissance officers, should be skillful place sketchers, since this ability will save the time ordinarily used in explanation of important features of the terrain to battery or battalion commanders and enable the batteries to open fire more quickly and accurately than otherwise.

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Points to be Observed in Sketching

69. *(1) Be sure your intersection and resection points are well marked to avoid sighting back on the wrong point.*

(2) Study your area carefully and do not sight any point that is not going to help your work. There is a tendency with all beginners to try to show too minute details and to take too many controlling points. A few minutes used in studying the area before commencing work will usually be well spent.

(3) Keep constantly in view the scale of your sketch, the contour interval, and remember the smallest distance that can be shown.

(4) Be sure your orientations are correct and that the Board is clamped after orientation. The forward sight to the next station should be made as soon after orientation as your position is plotted.

(5) After the first set up always orient by a back sight if possible, especially if in the vicinity of iron, or strong electric currents. However, if you can't locate a point in rear to orient on, use the needle without hesitation.

(6) Do not leave a station until all the details up to that point are put in. You may not have time to return that way. Finish your sketch as you go, the lines may be retraced and the sketch cleaned up indoors if the emergency demands it, but all data should be put on in the field. *You should make it a fixed rule to have a finished sketch up to the point occupied, before moving on to another.*

(7) Try to put equal care and time on all parts of the sketch. Avoid excessive care at first followed by excessive haste near the end. A good sketcher should be able to do from one to two square miles of accurate sketch per day depending on the difficulty of the ground.

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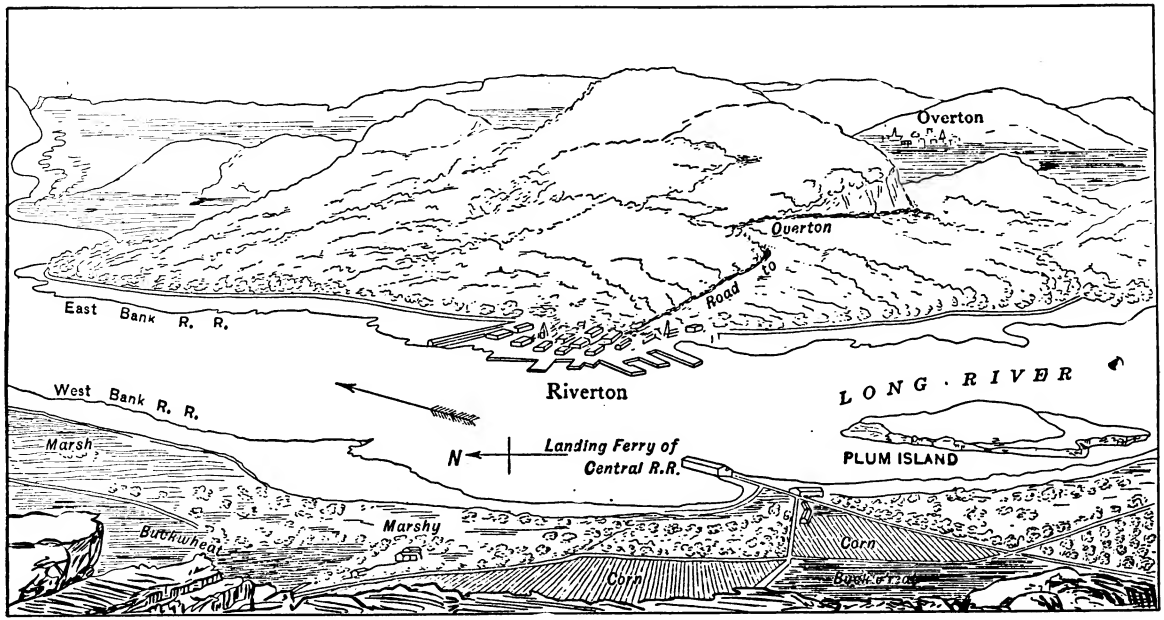

FIG. 31

Landscape Sketch

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Landscape Sketching

70. A trained map reader can get more detailed information from a contoured Place Sketch than from a Landscape Perspective Sketch, but not all officers can read maps readily, therefore a landscape sketch is often useful in illustrating a reconnaissance report. See figure 31.

Free-hand sketching cannot take the place of topography, but it is a valuable adjunct and should be practiced by every soldier who has any aptitude for pictorial drawing.

A Landscape sketch differs from a photograph only in that it shows in sharp outline a limited number of the larger and characteristic features easily seen and understood, while the photograph shows all details, many of them so minute that they are lost in a mass of confused forms, with the form lines, other than the sky line, relatively inconspicuous. All the lines of a perfect sketch exist in a photograph, but close scrutiny is often necessary to find them. If sought out and traced, a perfect sketch results. Tracing from photographs is excellent practice.

The Outfit for field landscape sketching should be as simple as possible. A sketchbook with a canvas cover, carried in a water-tight case, together with a few lead pencils, B, F, and H, and pieces of soft and hard rubber are the essentials for satisfactory work. For active field work the book should be no wider than can be carried in the pocket of a service blouse, and relatively long, say 5 to 9 inches.

The Point of View should as a rule be high enough to give a comprehensive grasp of all that is important—a rock, a knoll, a hill, a peak—depending upon the conditions. Face toward the middle of the field of view which is determined upon. Hold the board or sketchbook vertically before the eye and move it backward or forward until the sheet just fills the field. Lower the board until the sky line of the hills can be seen above its top edge, and with a pencil mark on that edge the points correspond-

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ing to the principal salients and reëntrants of the hill forms. If desirable the board can be moved sideways far enough to enable the principal heights and depressions to be marked on the vertical edge. By intersecting references the locations can then be easily established on the sheet. From these points the forms can be sketched in with much greater accuracy.

Proceed next to draw the hills in outline, but faintly, with attention to the larger curves or humps at first. Go over them again with more care, bringing out the small irregularities. If any part of the horizon is visible, draw in lightly, and then complete the general mass of hills by drawing the water or base lines. Seek now for the surface character of the hills by tracing the ravine lines. The knobs and foothills are brought out by tracing the tree meanders that show form. All changes in form or breaks in the ground produce corresponding breaks in the foliage of the tree masses, which show in the distance as irregular lines. If the more important of these are sought and drawn, the general character of the hill will result. Add now the foreground crest, and the skeleton of the sketch is complete.

The road and railroad meanders should follow as a rule, the fences of the fields. Cultivated land is rendered by parallel irregularly broken lines. Houses, fortifications, trenches, etc., will be drawn more or less in detail according to distance and importance. Enemy's lines or trenches even at a great distance should be strongly marked by simple black lines. The indication of forests and trees is the most difficult feature for students. The indications given in the accompanying sketches will show the treatment in outline work.

"Description and sketch from *Engineer Field Manual.*"

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CHAPTER III

Detailed Method of Making Road Sketch

71. The equipment used in road sketching is in general the same as in position sketching, except that the tripod is often omitted from the sketching board, and instead of the sketching board a Cavalry sketching case may be used. A stop-watch and note pad, figure 32, is useful for mounted work.

Method of Work Dismounted

Under service conditions a road sketch is normally made mounted on account of the rapidity of work thereby secured. It is well, however, for the beginner to make his first few sketches dismounted putting in only horizontal details to become accustomed to the three inch scale, before attempting to manage a horse in addition to the work of sketching. He should then go over the same course and put in contours dismounted before trying to sketch mounted. There may be occasions, too, when a horse is not available, so that a sketcher should be able to work with equal facility either mounted or dismounted.

The method previously given for traversing the base, A B C figure 26, in making a position sketch is, in general, identical with that used in a dismounted road sketch, except that intersection locations are not usually required at more than four hundred or five hundred yards from the road, and no resection work is usually possible. A large part of the work is done by traversing the road and estimating offsets. After the first one or two sketches, the sketcher will not usually leave the road, except to go to the top of some crest a few yards distant to get an extended view. Details will be limited to four hundred yards from the road, except for prominent positions, etc.

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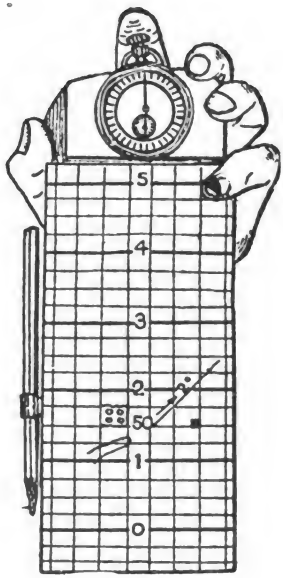

FIG. 32

There will often be areas within the 400 yard limit, which are not visible from points directly opposite them on the road. These areas, however, may usually be seen from some point along the road before or after passing opposite them.

The drawing board may be used in road sketching, with or without the tripod. If the tripod is used in mounted work it should be folded to a single length, figure 33, as it thus furnishes a firm support and also a convenient hand-hold for carrying the board on horse back. More accurate work can be done by using the tripod in this way, without loss of time, than can be done by holding the board in the hands. Some good sketchers use a board with wrist strap, and for important sights place it on the ground and lie down prone on the opposite side of the board from the point sighted.

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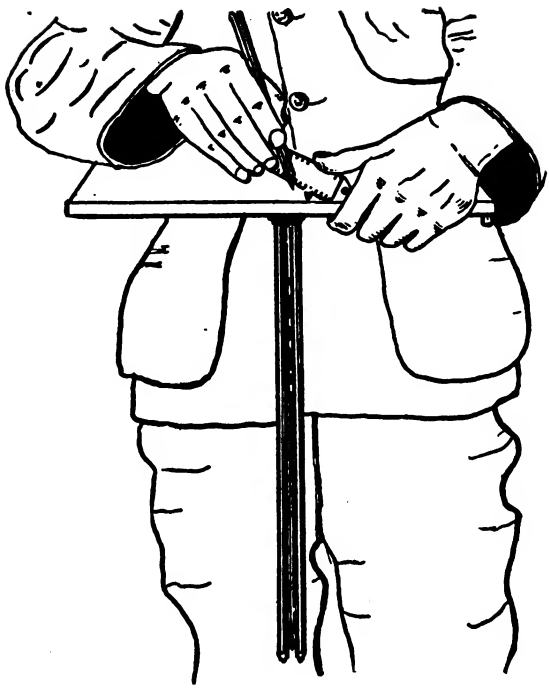

FIG. 33

In unimportant sights and in locating details around any station, even when the tripod is attached, the board need not be set upon the ground but is held pressed against the breast, figure 33. The sight is taken by fixing the eye on the distant object and then glancing quickly down at the ruler and making the necessary adjustment of the ruler's direction. In practicing this method, you should use a board on tripod and check each sight by carefully looking along the ruler. Never sketch with the cord holding the board around your neck.

The method of using the Cavalry Sketching Case is identical in principle with that of the drawing board without a tripod.

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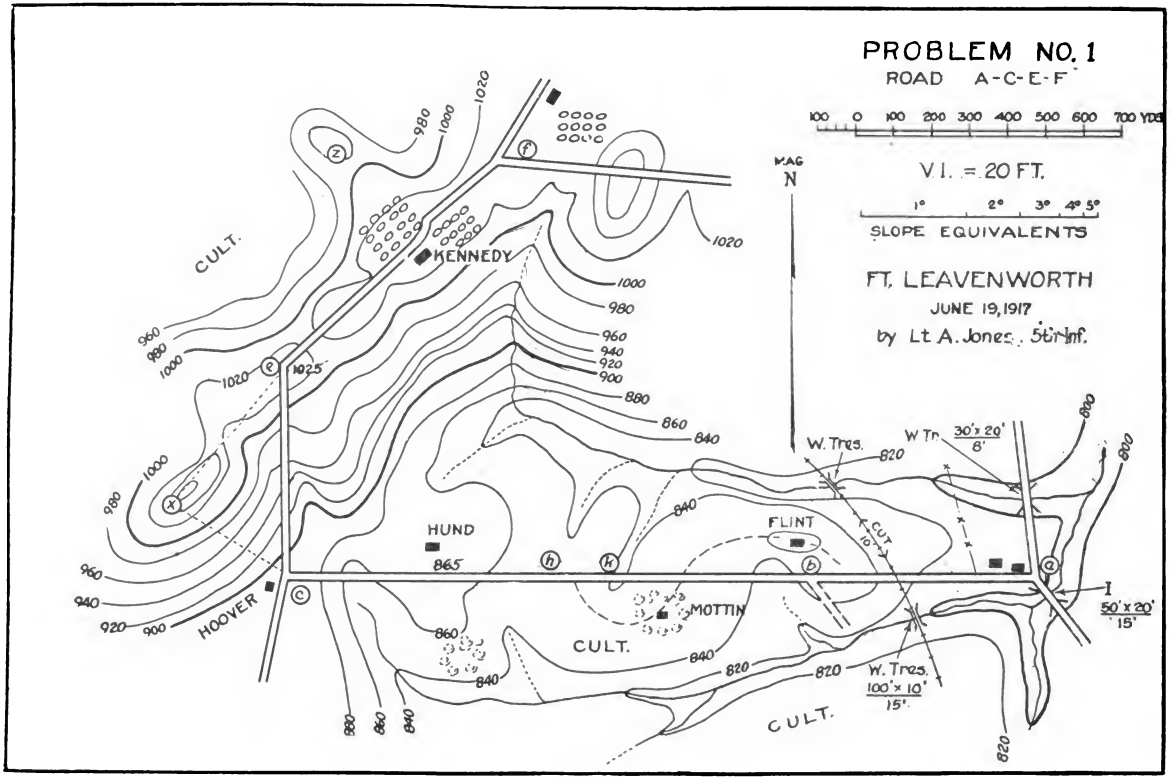

FIG. 34

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A sketcher having learned one of these instruments will have no difficulty in using the other.

To Locate Horizontal Details

72. (1) *Orient the board,* par. 55, at station A, figure 34, holding it in front of your body, that is between you and the object sighted. By glancing every moment or two at the declinator (or compass) see that the needle remains in the meridian. With the declinator, the orientation is effected most rapidly and is free from possible errors of needle reading. The sides of the declinator trough check the vibrations of the needle, and the orientation is correct when the needle strikes both sides of the trough with equal force. This can be easily determined by observation, and by listening to the click of the needle against the sides. To orient rapidly, note which side of the trough the north end of the needle (marked N) rests against, rotate the board continuously in this direction until the needle leaves this side and *swings equally on both sides of the meridian.* If the needle is very sensitive it will not come to rest quickly but you need not wait for this if you observe the above rule as to equality of swing. Remember to *see that the orientation is correct during all important sights,* especially along the main traverse. The needle of the Cavalry Case being very short and often sluggish, may appear to be more easily kept on the meridian than a longer needle. This does not mean that the orientation thus secured is better, but quite the contrary.

(2) *Take a forward sight along the traverse* toward B. Next sight the prominent critical points within three hundred or four hundred yards of A, figure 34, for example, the directions of road to the north, and southwest up the stream south of A B.

In making this sketch, you observe that the road A B is generally straight for a mile or more; you can therefore afford to spend a little extra time on this forward sight along the traverse, because of the amount of sketching depending on it

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and the consequent necessity for accuracy. Traverse to station B, noting the strides recorded on the tally register opposite the wire fence and railroad track. You should be able by this time to record your strides so automatically, see par. 49, that *your entire attention can be given to the study of the details to be put in.* You observe that the stream north of the road A B runs parallel to it at about two hundred and fifty yards distance. At first you would verify this estimate by halting at the railroad crossing and taking an intersection sight on the bridge north of A. You also observe in passing that the wire fence, noted before, runs parallel to the road north from A. At the railroad you observe that the track is almost perpendicular to the road on the south, and curves off to the northwest into a cut ten feet deep and one hundred and fifty yards long.

Methods at B. Having reached B, orient the board, plot in the roads branching from A and all details between A and B, first scaling off the distance to the wire fence, railroad track and B. The best method of doing this sketching in of details is to sit on the ground facing toward A, and draw in all details free hand, except roads and fences. The board need not be exactly oriented for sketching in details. With a little practice parallel lines for road boundaries can be easily drawn with the ruler. First draw the further line, then slip the ruler toward you and draw the nearer one. This allows you to keep the one first drawn in view and enables you to get the two parallel.

The conventional signs for roads, trees, houses, etc., should be drawn about the size of those in the figure. Telephone and telegraph lines are sufficiently indicated by conventional signs *at wide intervals.* Information concerning bridges may be shown as indicated in the sketch for the railroad bridge, figure 34 (w. tres. $\frac{100 \times 10}{15}$), meaning wood trestle, 100 feet long, 10 feet wide, 15 feet high; or it may be tabulated on an edge of a sheet as for bridge (1) and (2), figure 26.

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Having located the details from B to A, sight the stream junction southeast of B, to complete its location. Continue the traverse in the same manner to C, halting from time to time to *plot the details in rear of the point reached.* At C orient the board carefully, sight along the new direction of the road to the bend at E and toward the prominent hill top X. (If you are using the short tripod your orientations should be by back sight; if you are holding the board in your hands, the orientation will be by compass.) Take a sight to F to serve as a check on the traverse to that point by way of E. Where a stretch of road has a number of small bends, but is generally straight, these *accurate check sights far to the front are valuable* in keeping the correct direction, the small bends being drawn in by estimated offsets at the number of strides noted in passing them. To take a large number of short sights of one hundred and two hundred yards tends to accumulate errors. *In a long traverse in one generally straight line* as from A to C, *strides should be recorded continuously* for the entire distance, to avoid confusing the point from which the plotting is done and the accumulation of plotting errors. Having reached E, orient the board, plot E and sight X to finish its location. Sight Z.

Now traverse to the crossing F, without halting at Kennedy, but noting the number of strides to the road bend, to the house, and to both ends of orchard. Houses at cross roads (or other prominent points) should be located in their correct position, and the names of owners should be shown, for use as landmarks in the designation of routes of march, etc.

Having arrived at F, you would continue the sketch in the same manner as already explained.

Contouring the Road Sketch

73. Having located the horizontal details of the sketch, you should go back over the road putting in contours. (It is assumed here, for purposes of description, that you start in again at A to

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put in contours.) Looking north from A you observe that the ground rises only two or three feet above your present position and falls below your level (800) at the stream. You verify this by noting that the zero reading of the clinometer strikes the ground just beyond the bridge. Orient the board and draw the 800 contour up both sides of the stream to the point estimated as at your present elevation. Also draw in the 800 contour on both sides of the stream in the immediate vicinity of A.

Move to B, and read the vertical angle to A (—1½°), being careful to sight a point as high above the ground at A as your eye is above B. Apply your 1½° M. D. and find it contained two and a half times between B and A, or B is at elevation 850.

The 820 and 840 contours must be put in between the two stations. You observe that the ground near A is flat with a rise of about three degrees near the railroad track, so space the contour to show this. In all your road sketching be sure that the contours (especially on every steep slope) *show accurately the slope of the steepest part of the road* to convey to the commander correct information of the heaviest slopes over which the trains must pass. The spacing of contours on the flatter portions is less important, but must show the character of the slope—concave, uniform, or convex.

Now read the slope to the stream junction to the southeast (—3½°). Remembering that you are at 850 elevation, and noting that the slope is uniform, you place 840 contour about ½ a full M. D. from B.

You now observe that the Flint House is only about 10 feet above you, and consequently that there can only be the 860 contour around this hilltop as shown. To verify this you read the angle to the highest point of the hill and find a +2° slope just west of the house. Application of M. D. scale shows the hilltop is 15 feet above B or 865. You now draw in the contours on both sides of the road between B and A as shown, spacing them

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to show correctly the ground forms and slopes. The contours should be numbered as soon as finished.

The difficulties which you encounter at this station B are exactly those encountered at all subsequent stations throughout the work, but what seem to be insurmountable obstacles to you at first, will gradually become perfectly simple. And this skill will be acquired quickly or slowly, *depending on how carefully you analyze the essential elements of ground forms around each station* in the early stages of the work. The beginner arriving at B looks around him hopelessly trying to pick out the important points to be considered; but as he grows accustomed to the work he will grasp at a glance the critical points to be located and the details to be shown. *Constant study in converting ground distance to map equivalent, and in plotting the location of the contours around the station* is most valuable practice. You now look ahead and observe the slope of the ground on both sides of the road, and note that the road falls gently about 12 feet at the first draw, then rises nearly to the height of B, opposite Mottin. You also observe that there is a ridge line (shown dotted in the figure) extending along the north side of the road from Flint to Mottin, where it crosses through the grove, and that consequently the 840 contour must be about equal distance on each side of this ridge line, since the slopes of the hill near its top seem uniform.

Carrying Elevations Forward.—From B you can see the road some distance forward; therefore lie down with your eye near the level of the road and take a zero clinometer reading forward. This line of sight strikes the ground about 15 feet below the top and some distance east of the ridge at Hund, and strikes the trees at Mottin about 4 feet above the road. Note this point near Hund for later reference as at 850 elevation. Note carefully the shape of the ground forward, especially the relative heights of the points where ravines cross the road. The horizontal loca-

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tion of these points have already been determined in your previous work over this course to locate horizontal details. The question often comes up as to the necessity of taking the vertical angles to each small depression such as H and K, where you can readily see that no contour, or at most but one, is to be put in. Such observations are impracticable and unnecessary and would give less accurate results than a direct estimate of the height of these points on account of the short distance involved.

Now move to the high point north of Mottin, and looking back observe that B seems a little higher than your position, so you read the angle and find it about (+¼°). Being curious to see how this agrees with your estimate from B (see above), you apply the scale of M. D.'s and find the difference about 6 feet. In order that direct estimates of differences of elevation may agree with those found by clinometer reading and scale of M. D.'s, you must have determined your stride scale correctly; and your clinometer must be in adjustment, or its error known.

Now draw in the contours on both sides of the road back to B, making a careful estimate of their position, and noting that the ridge is flat topped and convex shaped.

You already have a reference point of elevation located; so proceed to the top of Hund Ridge, studying the ground and noting the number of strides opposite the selected reference point. Estimate the difference of elevation between your position and the reference point (15 feet) and verify it by a slope reading and application of M. D. Continue the work of contouring in this manner throughout the sketch, slowly and with many measurements at first, but gradually depending more on estimates of slopes, elevations, and contour positions, as you acquire skill in analyzing ground forms. For instance, from B you should have made an estimate of its height above A to see how it checked with your other determination; similarly the height of Hund Ridge should have been estimated from B.

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Road Sketching Mounted

74. After you have made two or three dismounted sketches, it is well to begin mounted work. The general methods involved are identical with those used in the dismounted work. The greatest difference arises due to the *necessity for controlling the horse,* in the *greater training of the eye required* to fix in mind the ground forms while moving rapidly from one station to another, and the *necessity for a more systematic method of work* to secure rapidity. When mounted you have a considerably better position for observation of the ground on account of your height above the surrounding country. You should *do all plotting dismounted* because of the greater rapidity and accuracy of working in this position. The time required to ride between stations at a trot and to dismount and mount at each is small compared with that required for the actual work of sketching. *Every step of the work should be done according to a fixed system.* For instance you should work out one definite method of carrying your board; one certain position to take for sketching immediately on dismounting at each station; a method of keeping time notes, and of keeping the horse at a uniform gait, a definite order of plotting distances, details, and contours. For method of rating horse, see par. 86 of Appendix.

Use of an Assistant. If you have an assistant, decide whether he is to keep the uniform rate; to learn the names of owners of houses; to read slopes; to call your attention to details such as orchards, windmills, telegraph lines, cross roads, etc. Each man must work out the system best suited to his own needs, but the following suggestions are offered (assuming that you have no assistant) for carrying pencils, clinometer, etc.:

To Move Between Stations. On starting from a station *stop the needle,* swing the board over your back, figure 35, and grasp the reins in the right hand. Best control of the horse can be secured by tying a knot in the reins in front of the pommel, and

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grasping this knot. The folded tripod does not interfere with your freedom of action in taking notes. The left elbow is supported by the board and in turn presses the Board firmly against

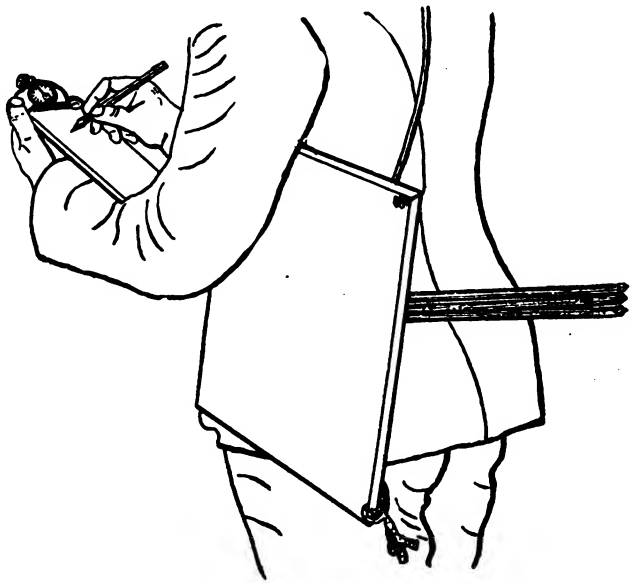

FIG. 35

your side. If you have an assistant he should carry the Board, grasping the tripod at its top.

Immediately on mounting take the stop-watch-and-note pad in the left hand, figure 32.*

* The stop-watch-note pad may be purchased through Secretary, The Army Service Schools at 35 cents each. It consists of a piece of heavy cigar box board 2¾x9 inches, to which is glued the note pad shown. Each fifth horizontal line is marked to show minutes of travel. The three light lines between each two heavy ones represent 15 seconds (quarter minutes) each. The spaces between the vertical lines represent 100 yards each. The stop watch is secured to the back by two wooden pieces secured on. The best type of stop watch is one which can be stopped and then will continue forward from this point when the stop is pressed again, so that continuous record may be kept over long straight courses. The watch should have a device for quickly setting the hand back to zero. A football timer (price $1.50

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Secretary Service Schools) is fairly satisfactory but not as reliable as a good stop watch. It is well to make a pencil holder on the side of the pad, as shown in figure, for a soft blunt pencil, so that the drawing pencil need not be used in taking notes.

At the moment the horse starts, press the stop with first finger to start the watch, being careful to see it is set at the proper reading.

Taking Notes on Horseback.—As important details are passed along the road, note the time and opposite the proper line of the pad jot down a rough symbol on the center line or at the estimated distance from it, according as the location of the detail is on or off the road. These notes will be a great aid to the memory; but as little time as possible must be spent in putting them down, the greater part of the time being used to impress features of the ground on your mind. Some men find it very difficult to make even the simplest note on a trotting horse; but you can learn to keep sufficiently clear notes on even the roughest horse, by standing up in your stirrups, leaning the body well forward and holding the arms close against the sides while writing. You can also record notes while posting. During the entire time spent in passing from one station to another, except for the brief intervals required to record notes, you should devote every faculty to a careful study of the ground, the trace of contours, and other essential details.

Distance Between Halts. In the first two or three sketches you should not travel more than about one minute between stations. Later this distance may be increased as your skill progresses until you can travel for 3 or 4 minutes without halting. Suppose you pass a little draw on the road (at 1 minute and 15 seconds) falling to the left; a house distant 190 yards to the right at 1:30; an orchard on the left extending from 1:30 to 1:45; a ridge line at 1:30 found to be 850 elevation from your last station, extending 45 degrees to right front with a —2 degree slope. These facts can be recorded in a moment as shown on the pad. Or some simple system of letters may be used, such as R for ridge, V for valley, on line in the proper direction; an arrowhead for down slopes, etc.

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Procedure at a Station. On arriving at a station, immediately upon halting press the stop to get the correct time. Dismount, throw the Board cord from over your head, release the needle, spread out the tripod legs, at the same time rotating the board horizontally to orient it. Back sight orientation is more accurate and will often be possible even when no tripod is used, by laying the board on the ground, and turning it until the last station is sighted. Waste no time in orienting.

The horse should be trained to stand without being held; but if necessary throw the rein over a post or place your foot on it (if you have no assistant). With tripod, you will find it easier to take your observations for direction kneeling on the opposite side of the Board from the point sighted. For sketching in details, however, a sitting position on the road side is best and most comfortable. After your traverse and other important directions are located do not worry about keeping an exact orientation during the work of sketching details. As soon as your Board is oriented plot your present station; pick out and sight your next forward point, also take any intersection or forward check sights, so that exact orientation will then not be so necessary for the remaining work. Determine the elevation of your present station with reference to the last known point by the methods heretofore given, that is with clinometer and M. D. scale, or barometer, or estimation, etc., according to the practice you have had. Locate any other necessary elevations and plot all details and contours up to your position. After several sketches have been made, you can begin to plot details forward from each station for about 15 seconds of travel, by estimation. This will relieve you of the necessity of taking notes until about 30 seconds have been passed. Move to next station using the same methods.

In rapid sketching, time may be saved on roads with frequent bends by *halting only at each alternate bend.* For example from C draw a ray to E, noting the time of passing E but not halting

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there. At F plot *e* on the ray drawn from C; orient by needle, and pivoting the ruler on *e* draw a ray toward F, plotting on this ray the position of *f* from the time scale.

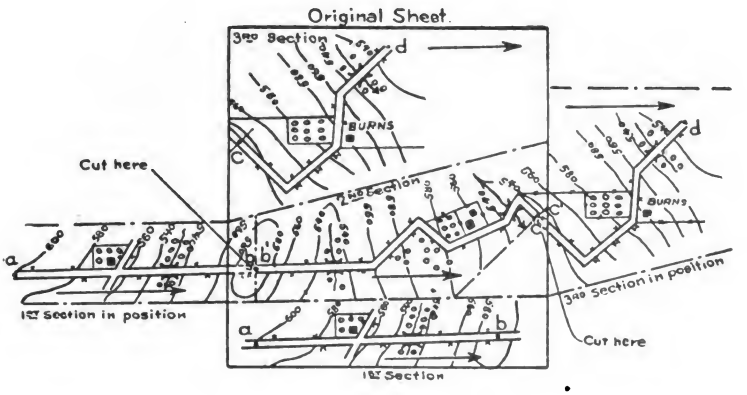

FIG. 36

75. *In case the sketch runs off the sheet* beyond *b*, figure 36, draw in the details a few yards *in front* of station B. Then assume a new point (*b'*) near the edge of the sheet, also to represent B, so chosen that the sketch forward from here will fall across the longest dimension of the unused part of the sheet. On the sheet near *b'* sketch in the details a few yards *in rear* of B, before moving forward. If no space is available on this sheet replace it by one of the extra sheets carried under it on the Board. When the sketch is completed, cut apart its different sections (on the broken and dotted lines) and place them together with all meridian edges parallel and *the two corresponding points on the sheets for any ground point, lying one directly over the other.* Lay the ruler perpendicular to the traverse through the station point (as *b*) and cut both sheets through on this line. Remove the two ends cut off and join the parts together *without overlap* by means of adhesive tape or on another piece of heavy paper. Join up the details across the cut edges. Where the sketch is made on

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tracing paper and reproduction is required, the adhesive tape should be used. B, C, etc., should be on a straight portion of the road and *not at a bend,* to aid in orienting the sections.

The *rate of sketching* possible by these methods should be about 2 to 2½ miles per hour for men of average ability, after a month's practice. Men with greater aptitude can make from 3 to 4 miles per hour; and the best sketchers can make as much as 5 miles per hour. These rates refer to the *completely finished* sketch, ready for use. In ordinary service 2½ to 3 miles an hour would be sufficient, but the more rapid methods are very valuable for making a reconnaissance in a limited time, and of especial value to staff officers in reconnoitering routes and positions.

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CHAPTER IV

Exercises in Sketching

76. Sketching consists of measurements and estimates of relations on ground and maps, and more or less mechanical operations with pencils and scales. There will be a large number of distinct operations in any single sketch. And though each individual operation is in itself simple, yet the beginner who attempts at first to draw a complete sketch is invariably lost in a mass of details, imperfectly understood after a more or less careful reading of the text. Consequently, it is important that each detail be mastered singly; not by a study of the text alone, but by study supplemented by practice on the ground. To assist beginners in sketching who have no instructor, and as a guide for a systematic method to be followed in the instruction of classes, the following exercises on the ground are suggested. These exercises should be conducted in the vicinity of the Post on ground which has been previously sketched by a good sketcher or of which an accurate map exists:

Area 1. For position, outpost and place sketches, an area about ½ to 1 square mile is sufficient. Scale 6″ = 1 mile, V. I. = 10 feet.

Area II. For road sketching exercises a road sketch or map about two miles long is necessary. Scale 3″ = 1 mile, V. I. = 20 feet. Each beginner should be furnished blue prints of these areas.

Exercises

The work should be taken up in the following order: frequent indoor practice in tracing the contours on a well drawn map, in

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order to acquire facility in representing the forms later to be observed on the ground; then take up position sketch, outpost sketch, road sketch, place sketch. The paragraphs of the text referred to should be diligently studied before the particular exercise is undertaken, and should be read as necessary during the exercises.

Position Sketching

Exercise 1.

(a) Determine your stride (par. 49).

(b) Make a working scale of strides (par. 15).

Note: Those who have difficulty in making scales may secure them of any desired length of stride or rate of speed from the Secretary Service Schools.

(c) Test the correctness of the scale (par. 18) and make any necessary changes in it.

Exercise 2.

Choose in Area I some road or path having frequent changes of direction and varying slopes. Traverse this road (par. 55) plotting only the double lines (for width apart of bounding lines of roads see figure 27) or a single dotted line for the path. Halt (a) at every change of direction, (b) at every change of slope, (c) often to estimate the distance to points in advance on the route. The halt (a) is first for the purpose of noting and plotting the new direction on the sketch; the halt (b) is made to estimate the slope, par. 62, and difference of elevation (par. 63) from top and bottom of the slope. Having made all of these estimates as carefully as possible, check each of them by comparison with blue print, using the scale of M. D's. to verify the slope, the marked elevations or contours to check elevations; the counted strides to check the distances.

Now having fixed to your satisfaction the slope between the two points, space in the contours along that slope on your sketch by eye, checking the estimate with scale of M. D's. (par. 64). Next note the number of contours along this slope from the difference of elevation between its top and bottom. Space these

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by eye to show the particular kind of slope. Check the results from the blue print.

Repeat the above exercises until (1) your length of stride is accurately found (2) you thoroughly understand the methods of orientation and plotting of the traverse and the making and verifying of estimates.

NOTE: Exercise 2 is to develop a fixed habit of verifying all estimates. Rapidity comes later.

Exercise 3.

Traverse the same road as in exercise 2, performing the same operations and in addition, locate by intersection (par. 56), (a) the top of each hill, (b) the juncture of each two streams and water flow lines, and their heads in both sides of the traverse for ½ mile. Use field glasses to pick out definite points to sight on and see if you are at any time unable to get a second observation on any point sighted. If so find out why, and try it again. Much time is wasted by taking one observation on points and then not finishing their location.

Next move back over the traverse and (a) estimate the slope to each point located, (b) check the estimate by reading the slope with clinometer (par. 83). Then estimate the difference of elevation from your stations to these intersection points. Space the contours by eye, checking, etc., as in exercise 2 for work on the traverse.

Exercise 4.

Having traversed the road in exercise 2, set up your board (par. 55) at a station on it, and plot the direction of three or four hill tops off the road. Move to one of these hills and set up in the direction line observed and locate yourself by resection (par. 57). See how this location agrees with that by intersection on this point. Repeat on each of the other hill tops sighted, until you are entirely familiar with this method of resection.

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Next locate points by resection using the needle for orientation (par. 57, 2nd method) and compare the results obtained with those by the first method of resection.

Exercise 5.

(a) Pick out a base line in Area I and see how well it fulfills the conditions of par. 59.

(b) Traverse this base (par. 60), locate critical points over the area by intersection and resection.

(c) Go back over the area and sketch in by eye the horizontal details (figure 26) such as streams, water flow lines, roads, railroads, telegraph lines, trails, crest lines of ridges, hill tops, orchards, houses, etc.

Exercise 6.

(a) Begin at your initial station and locate the elevations of all critical points by estimation (par. 63), checked by slope readings and application of scale of M. D's., par. 64.

(b) Having found the elevations of the critical points space in the contours by eye, checking with the blue print.

Exercise 7.

(a) Make a complete sketch of the flat details as in exercise 5 on an entirely new area.

(b) Contour the above as in exercise 6 above, par. 64.

Exercise 8.

Make the complete sketch of the area in exercise 7, showing at the same time all horizontal details and the contours par. 65. In this exercise finish up all work in rear of each station before leaving it.

Exercise 9.

(a) Select an outpost line and traverse this as a base at the same time locating critical points as far to the front as the ground is visible (par. 67).

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(b) Return along the base drawing in all horizontal details and contours as indicated in preceding exercises.

Road Sketching

Exercise 10.

(a) Make your scale of strides at 3″ to 1 mile, par. 49.

(b) Rate your sketching horse (par. 86) at a walk and trot.

(c) Construct a scale of walk and of trot (par. 86 and par. 16, prob. 3).

Exercise 11.

(a) Traverse (par. 60) the road, Area II, dismounted, locating flat details on the road, and, by intersection, to within 400 yards on each side. Each point should first be estimated as an offset (par. 58) and then checked by careful location.

(b) Go back over the road and contour it by estimating the elevations of critical points, par. 63, and the contour spacing, par. 64.

Note: Remember that contours are spaced the same distance apart for the same slopes on both road and position sketches (par. 26).

Exercise 12.

Make a complete contoured sketch carrying on the horizontal locations and the contours together, along the road, in exercise 11, par. 65.

Exercise 13.

Repeat exercise 11 mounted (a), at a walk (b) at a trot, par. 74.

Exercise 14.

Repeat exercise 12 at a trot, being careful to have a complete sketch up to each occupied station and about 15 seconds in advance before moving forward.

Exercises similar to the above may be drawn up for place sketching following the principles in the text.

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CHAPTER V

Reproduction of Maps

Maps may be reproduced photographically or mechanically.

77. Mechanical Reproduction: 1. *By tracing.* Fasten a sheet of tracing paper or tracing cloth over the drawing to be copied. The details will show through and are followed in pencil or ink. The rough surface of tracing cloth takes pencil or ink.

2. *With carbon paper:* Place the sheet of carbon paper over the sheet to receive the copy. Fasten the map on top of the carbon sheet, and trace with an ivory or similar point the lines which are thus impressed on the copy-sheet underneath.

By Squares: Divide up the original area of the map into a series of squares, one to two inches on the side, depending on the amount of detail to be shown. Number all the squares serially beginning at a corner of the area. Divide up the sheet on which the copy is to be made into an equal number of squares similarly numbered, with sides of a length proportional to the change in scale (linear dimensions) to be made in the map. That is, the sides to be $\frac{1}{2}$ those on the original map if the scale is to be reduced one-half; double if the scale is to be multiplied by two. Draw in on each square of the reproduction the desired details in the corresponding square of the original. As a rule these locations can be made by eye, but for each very important point two measurements may be made perpendicularly from the nearest edges of the square.

By Pantograph: Figure 37 shows a simple pantograph and its operation. One point is fixed while the tracing point is moved over the original and causes the pencil point to draw the repro-

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duction. The pegs shown at the center of the board are adjustable and may be set at the desired ratio of enlargement or reduction, as marked by holes on the sides of the parallelogram.

Photographic Reproduction

78. 1. *By blue printing:* A sheet of blue paper (sold by any photographer) is secured to the tracing of the map by clips or in a photograph printing frame. It is then exposed to the sun from four to eight minutes, until an edge of the paper has a greenish bronze color, the paper is then removed from the frame and placed in a basin of water, rinsed for three or four minutes

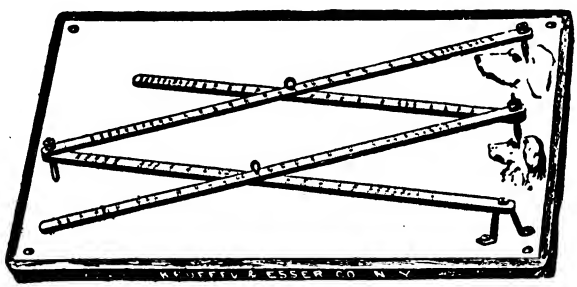

Fig. 37

under the tap and dried. This is one of the quickest and most useful methods of reproduction, because original field sketches made in pencil on tracing paper can be blue-printed at once without retracing. Brown Prints are similarly made.

2. *From a negative:* A negative of the map is made with any kind of camera, in the ordinary way. From this negative, direct prints the size of the negative may be made, or enlargements may be made on bromide paper to any desired size. A description of the details is not within the scope of this book, but such copies can be secured from any photographer. More rapid methods for securing a large number of copies, such as by lithography, are not usually required by Line officers.

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CHAPTER VI

Topographical Reconnaissance Reports

79. *Reconnaissance* is the military term used to designate the work of troops or individuals when gathering information in the field. The general subject of Reconnaissance is divided into two parts: (1) that which relates especially to the strength, position and intentions of the enemy, and (2) that which relates especially to the terrain in its relation to the military situation.

Reconnaissance of the enemy is within the province of tactics and is treated under the head of the Service of Information in the Field Service Regulations.

By *Topographical Reconnaissance* is meant the obtaining and recording of all the needful information of a portion of the terrain in the shortest possible time and within the limits of accuracy required for the operations of troops in the field.

A Topographical Reconnaissance in general consists of:

1. *A Sketch.*
2. *A Report.*

The method used to secure and record the desired information of the terrain is therefore treated under the two headings, Military Sketching and Reconnaissance Reports.

As much as possible of the desired information should be shown on the sketch, on account of the greater clearness and brevity thus secured. The report should amplify the sketch in matters which cannot be shown thereon, such as conditions of roads, quantities of supplies, etc. It should in general be written on the face of the sketch sheet in tabulated form; or on a letter size sheet of paper attached thereto.

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Reconnaissance Reports: The Report should relate only to those subjects which are required by the orders for the reconnaissance so that no time may be wasted in gaining irrelevant information. It should be written clearly, and be as brief as possible consistent with clearness. The *paragraphs* should be *numbered* serially for ready reference. *References* to the sketch should be made by means of numbers enclosed in parenthesis, thus: *"Road* (1)—(2) 18 *feet wide, macadam, good repair."* It is well to place all numbered references on the sketch before writing out the complete report so that these references on the sketch will extend from beginning to end in order and thus be easily referred to. It is a good plan to make these references on the sketch in red pencil so that they will catch the eye at once. The report should be dated and signed by the officer making the reconnaissance.

Names of Places should be in BLOCK CAPITALS, and should be spelled phonetically when the spelling and pronuncation are different. *Relative Terms* (such as before, behind, etc.) should be avoided, points of the compass being used except that the terms "right," "left" are to be applied to the banks of a stream assuming the writer to be looking down stream. The term *"open country"* means that it is free from hedges, undergrowth and other obstacles obstructing view and passage; *"close country"* is the reverse of this.

A *Road Reconnaissance* should procure data on the following subjects:*

The Road: Gradients, especially the steepest; width of roadway; if paved, width, kind and condition of paving; width and depth of side ditches, and whether wet or dry; if not paved, character of soil, sand, clay or gravel; *kind of fences* and width between them. The sketch should also show whether the road is

*From the Engineer Field Manual. Items of a reconnaissance, shown in *italics* should usually be shown by the sketch; those in ordinary type by the report. Features not fully shown in the sketch are amplified by the report.

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an *embankment or cutting;* where wagons cannot double or pass, and where foot troops cannot march along the side between the wagon track and *fences; commanding heights within infantry or artillery range.*

Bridges: Material of piers and abutments, *type* and *material of superstructure,* as *girder, truss, arch, suspension, wood, steel, stone,* etc.; width of roadway, and clear headroom; safe load. Of bridges over the road, clear width and height; over streams, the nearest bridge above and below and whatever information can be obtained about them.

The Country.—Character of cultivation or natural vegetation; areas and density of timber, underbrush, vines, especially poisonous ones; *marshes and fords, kinds of fences,* nature of soil, *general configuration of surface, especially high hills, long ridges or valleys, bluffs or slopes too steep to scale, and practicable routes to their crests.*

Streams Crossed.—Name, location, width, depth and surface velocity in swiftest current; velocity noted as sluggish, moderate, quick or swift; elevation of high water marks in relation to the road; *which bank is the higher at crossing and above and below, and how much;* accessibility of water for stock; *fords at or near crossing;* length, depth and *steepness of approaches; levees or embankments, height and thickness on top;* if navigable, to what distance above and below and for what class of vessels—steamers, flatboats, rowboats.

Towns and Villages passed through—*Name, location on map,* and population. *Names of streets to be traversed.* Material, as stone, brick, frame, log; size, 1, 2, 3 stories; and distribution, close or scattered, of the houses in those streets; *gradients of intersecting streets; location of depots, post telegraph and telephone offices; of drinking fountains and watering troughs; of elevators, storehouses, or other accumulations of food and forage; of blacksmith, wagon and machine shops.*

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When ordered to make a complete examination of a town or village, note besides the foregoing, *location* and size of *principal buildings, halls, court and school houses, churches, banks, jails,* and their ownership; sources, maximum quantity and distribution of water supply; sanitary conditions and disposal of wastes; *location of railroads, depots, freight houses, sidings, etc.,* for all roads entering from the surrounding country the same information as scheduled above for streets; *location* and extent of *open spaces,* and of *large substantial buildings standing apart; location and extent of high ground within range, especially that from which streets can be enfiladed.*

Railroads Crossed.—Name, location, gauge, *single* or *double track, sidings, and loading platforms at point of crossing; crossing at grade, over or under; distance, and name of nearest station each way; direction of nearest roundhouse, shops, etc.* General condition of stations as to defensibility—*command of surrounding ground,* and material of construction in the buildings.

River Reconnaissance

If, when standing on the bank facing across the stream, the current flows from left to right, the observer is on the right bank; if from right to left, he is on the left bank.

The Valley—General configuration, heights of limiting ranges, and *positions of passes and roads crossing them; commanding ground from which a stretch of the channel of considerable length can be enfiladed by artillery; forest growth on or near banks;* soil and cultivation of the valley; *roads parallel to river and means of access* to them from the river.

The Stream—Its *width,* depth and velocity, navigability, as for steam boats, row boats, and head of navigation for each; nature of obstructions to navigation and possibility of removing or avoiding them; season of high and low water, average rise and fall; rapidity of rise and fall and causes; amount of drift; character of *banks* and *relative command.* Quality of water, amount and kind

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of sediment borne; usual period and thickness of ice. (Ice 2 inches thick will support single men; 3½ inches will bear infantry in column; 10 inches will bear any military load.)

Tributaries and Canals.—Width, depth and navigability, *means of crossing.* Nature and purpose of canals; *dimensions* and lifts of locks; time for lockage; means of destroying locks and effect of destruction; floating plant found.

Bridges and Ford.—As in road report. Also for bridges note position of the channel and navigable width between piers; height of arches and lower chords above the water at different stages; dimensions and operation of draw spans. Note the *exact position of fords* and marks on both banks by which they may be found; length, width and nature of bottom; velocity of current; position of deep holes; aids to crossing. Fords should not be more than 4 ft. 4 ins. for cavalry, 3½ ft. for infantry and 2 ft. 4 ins. for guns and ammunition. Note nature of approaches to bridges and fords; width of roadway, slopes, soil, effect of water and traffic. Note especially the defensibility of bridges and fords.

Ferries, Boats and other means of crossing.—Position of ferries and approaches, practicability for horses and loaded wagons; size, number and kind of boats; method of propulsion; sites for military bridges or ferries; character of site for construction, use and defense; *proximity of islands and other tributary streams;* approaches and slope of banks; width of river and maximum surface velocity of current; materials for the construction or repair of boats, bridges or ferries.

Inundations.—Places suitable for inundations by damming or obstructing a narrow bridge span, or *by cutting a levee or dyke.* Note raised road on ground liable to natural or artificial inundations and the safest routes to follow by known landmarks when the road is overflowed. (An extensive inundation 2 ft. deep on level ground is a serious obstacle unless the roads are very sound and marked by trees, posts, etc. Even when so marked a dip in

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the roadbed of 3 or more feet may render the road impassable. A railroad bed is soon washed out even by a slight overflow.)

Reconnaissance of a Railroad

The line. Local name, terminal points and distances between stations and other points; gauge; *single or double track;* condition of roadbed, ties and rails; drainage and liability to overflows or washouts; facilities for repair; condition of right of way for marching troops along the line.

Tunnels and bridges.—Number and location; dimensions; strength of bridges; means of destroying and repairing; of blocking traffic.

Rolling Stock.—Number and nature of engines and cars available; capacity for transporting troops between given points; facilities for constructing armoured trains, as spare rails, old boilers, etc.; *location* and capacity of the shops and store yards.

Stations: Name and location; facilities for entraining and detraining troops with wagons and horses; platforms on through line and *sidings, ramps; side tracks,* number and capacity; *turn tables; water tanks; fuel supply;* storage facilities; derricks or cranes; *cross-over for teams* and pedestrians. Facilities at hand for hospitals, camps, depots; for feeding men. heating coffee, watering horses during temporary halts.

Reconnaissance of a Wood or Forest

Note *all roads and paths,* and *all hills, ravines, and streams within the wood or skirting the edges;* kinds of trees, *density of growth;* underbrush, prevalence of poisonous shrubs and vines; *marshy or large open spaces;* practicability of forming new roads by cutting: creation of obstacles by felling trees; if there are no roads, *traverse the shortest practicable path between the point of entrance and the point of exit,* and mark boulders or blaze trees, set stakes or otherwise indicate this path, and also give compass bearings of the route to be followed. Note the *exterior*

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from the woods whether parts of the edge flank other parts; connection with neighboring pieces of wood by scattered trees or clearings; undulations of the ground that would give cover to attacking force or to defenders.

Reconnaissance of Mountains

Note the *number and positions of passes through the mountains, of roads and trails leading to these passes,* their condition, practicability, and means of repair; *steepness of slopes on the sides of roads;* means of constructing additional roads *water courses, their direction,* nature, and time of floods, *means of crossing.* Note *ravines* and *open glades on mountain sides, lookout points,* and *good signal stations;* note time and duration of snow drifts on roads or passes; depth of drifts and possibility of removing them or traveling on the surface of the snow. Note *extent* and nature of *forest growth.*

Reconnaissance for a Camp or Winter Quarters

Site, location, elevation, and area; sanitary features, such as drainage, dryness, and general character of top soil; *proximity of swampy ground or stagnant ponds.* (For areas required for camp sites see F. S. R., Appendix I.)

Communications.—Sufficiency of existing *roads and paths, maximum grades,* probable condition under heavy traffic and in bad weather, location and kind of materials available for improvement or repair; *railroad or water communications* and *terminal facilities of same.*

Water and Fuel.—Location, kind and quantity of fuel at hand; quality and quantity of water, facilities for filling water carts, for watering animals and for washing and bathing; nature of supply, as wells, springs, running streams, and its reliability.

Shelter and Conveniences:—Proximity of trees, brush, wood, hay, and straw for huts and bedding; *of markets; of towns and villages.*

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Reconnaissance of a Position

80. This problem usually includes the selection of the position and is therefore tactical as well as topographical. Certain relations and conditions must be observed in the selection and the extent and degree in which they are found must be shown on the map or in the report. *The position and ground in front* to artillery range, to be shown by a contoured sketch at 6 inches to 1 mile.

The length of the position should be proportional to the force available for its occupation. Exact rules cannot be given.

The flanks must be secure. Impassable natural features, a *river, a mountain* or *stream* form the best flank. Lacking these, a *wood,* a *cliff* or a *high hill* will serve. Even with these features absent the flank may be strengthened by the construction of a strong earthwork, but the general rule obtains that natural weakness of the flanks must be made up by a greater number of men or by the substitution of cavalry for infantry in case the ground favors the movements of mounted troops. If the flanks are naturally strong the line should be withdrawn to make the entire position reëntrant; if the flanks are naturally weak, the connecting line should be held so as to make the position straight or salient.

The depth of the position, or its extent in rear of the firing line, should afford natural cover for supports, reserves, and trains, which may require a total depth of 800 to 2400 yards; but a short position may be relatively shallower than a long one. Three or four *parallel ridges,* 300 to 600 yards apart, with the intervening ground practicable, form an excellent position. If the first ridge is somewhat higher than the rest, so much the better. *What cover there may be for the component parts of the force, whether natural or artificial, fences, ditches, trees, etc., should be shown* or described. If digging is necessary, its amount and the character of the soil should be stated. *Strong points in front of the line,* which may be occupied as outposts should be shown.

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Communication should be free in every direction, concealed so far as possible from the enemy's view. *All communications* perpendicular and parallel to the front to be shown on the sketch.

Artillery positions are required when that arm is represented in the occupying force, as will usually be the case. They should permit the guns to sweep all ground in front of the position over which the enemy can advance, to the limit of effective range. Every point in front of the position and within range which commands any part of it is an element of weakness.

Ranges at which the enemy can be seen and reached by artillery fire, the *points beyond rifle range covered* by such fire and its *relative command of adverse artillery positions should be shown* or described. If possible *similar information* should be obtained of the *ground likely to be occupied by the enemy* in forming for attack or in taking up a counter position.

A position occupied by the enemy must be reconnoitered from a distance and few details can actually be seen. Valuable inferences may be drawn by remembering that the enemy has probably chosen his position according to the principles above given.

Flanks.—Especial attention should be given to the flanks and to the feasibility of turning one of them.

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APPENDIX

Method of Using Compass and Protractor

81. *B is located from* A, by reading the azimuth (angular direction with respect to the meridian) of B from A with a Box Compass,* or Prismatic Compass, figure 38. The angle read

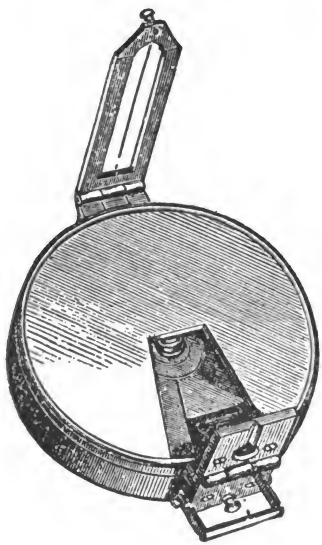

Fig. 38

is then plotted by means of an Abbott's Protractor, figure 39. In reading a box compass the needle should be damped, by

**To read an azimuth with the box compass,* partly close the lid until it makes an angle of about 120 degrees with the plane of the compass face. Then hold the compass in the left hand, in front of your body, and you will be able to see the reflection of the sighting line (*a-b* figure 13, Map Reading) in the glass cover. This reflection of *a-b* should be made to pass through the pivot while *a-b* is pointed toward B, at the time the reading is taken. The reflection will lie through the pivot only when the compass face is horizontal, thus giving the true horizontal angle desired.

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pressing the left thumb down on the stop several times, so that it will settle correctly. To save time, the reading may be taken at the middle of the swing of the north end of the needle.

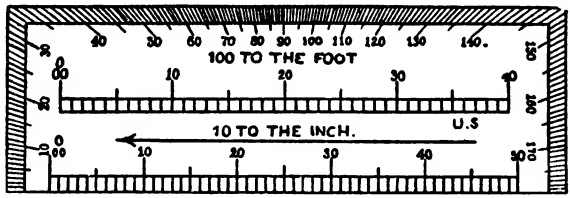

FIG. 39

82. *To Plot an Angle with the Protractor,* lay it along the meridian through the plotted position of the occupied station, the zero at the north, the center of the protractor on the station point. Make a light dot on the paper in extension of the angle read, and draw a line through this point and the station. The protractor is so graduated that it is laid on the east side of the meridian for plotting angles from zero to 180°; from 180° to 360° the protractor is turned over to the left side of the meridian. An arrow drawn on each side of the protractor will assist in rapidly placing it in position with the proper end north. In case the compass is graduated so as to give angles different from the azimuths of a normally graduated compass, mark on the protractor in ink the readings actually given by the compass.

To read an azimuth with the prismatic compass: The two sight leaves are revolved into position perpendicular to the face of the compass. This brings the prism directly over the graduated circle on the card. Now, holding the compass on both hands, place the eye at the peep hole in the rear sight vane. Look through the two sights toward B, at the same time damping the compass card by pressing the stop just under the front sight vane. You will now see the proper reading in the prism at the same time observing B. In this compass the "index" (line of sights) moves while the circle is fixed. In the box compass the index (needle) is fixed while the graduated circle moves with the sighting line.

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To Locate a Point D, figure 26, *by intersection with compass,* from two plotted points A and X, is accomplished by reading the azimuths of the unknown point from A and X, and portracting the readings from *a* and *x*. The intersection of these two lines is *d* on the sheet.

A Point Z, figure 26, *may be Located by Resection on Two Plotted and Visible Points C and K, with compass and protractor* as follows: At Z read the azimuth to K and C. Then lay the protractor on the meridian through *k,* and plot the reverse azimuth, that is the difference between 180° and the azimuth Z K. Similarly plot *c z* from *c;* the intersection of the two lines locates *z* on the sheet. The protractor method has one advantage in that the Board need not be oriented before making observations along the traverse or for intersection and resection. The Board must be approximately oriented, however, for sketching in details. Before going out to work, meridians should be ruled at ½ inch intervals over the sheet, as it is difficult to draw parallel lines rapidly in the field. Except for the above differences noted in making locations, the compass and protractor method is the same as the plane table method.†

†*The Advantages of the Plane Table* Method in reasonably open country are so many as compared with the compass and protractor method, that all are strongly advised to learn the former first.

Some *Advantages of the Plane Table Method:*

1. Once the board is oriented, it is difficult to get an incorrect sight because the ray is drawn while the ruler points toward the object.

2. It teaches the necessity of keeping the sketch constantly oriented, which is a most valuable habit in map reading as well as in sketching.

3. Greater rapidity is possible because of the smaller number and greater simplicity of sketching appliances.

4. By its use far greater skill is acquired in mastering ground forms and in learning to estimate directions.

5. *In using a compass and protractor, the following errors are liable to occur:* (a) Incorrect angle reading due to failure of compass needle (or card of prismatic type) to settle correctly; (b) failure to read the angle correctly; (c) failure to plot the angle read; (d) failure to adjust correctly the protractor on the meridian and the station point; (e) errors due to local attraction which can be thrown out in the plane table method by back sight orientation.

In close jungle compass and notebook will often be the best method.

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83. *The Service Clinometer,* figure 39 and 40, consists of a pendulum B with an attached arc graduated in degrees and half

FIG. 40

degrees rotating about the pivot N, and a mirror H, all in a brass case. In figure 41 the front of the case is removed. The observer sights the object through the peep-hole (E) and L, at the same time seeing the scale of degrees inside the rim at B′ reflected in the mirror H. The pendulum is allowed to swing freely by first sliding back the bar and pressing the stop D. The reading is taken when the pendulum comes to rest and the desired spot is at the same time sighted. *The pendulum should not be stopped to take the reading as this displaces the scale.* By holding the clinometer so that the zero of the scale is in the center of L, a good hand level is thus secured.

To Test the Service Clinometer.—Hold the clinometer, stop uppermost, against a post A, with E L, figure 41, on a level with its top and sight the top of a post, B, 50 or 60 feet distant. Suppose the angle read is minus 3 degrees. Similarly sight the top of post A from B. Suppose this reading is plus 2 degrees. Add the two readings and divide the sum by 2. The correct slope from A to B is then

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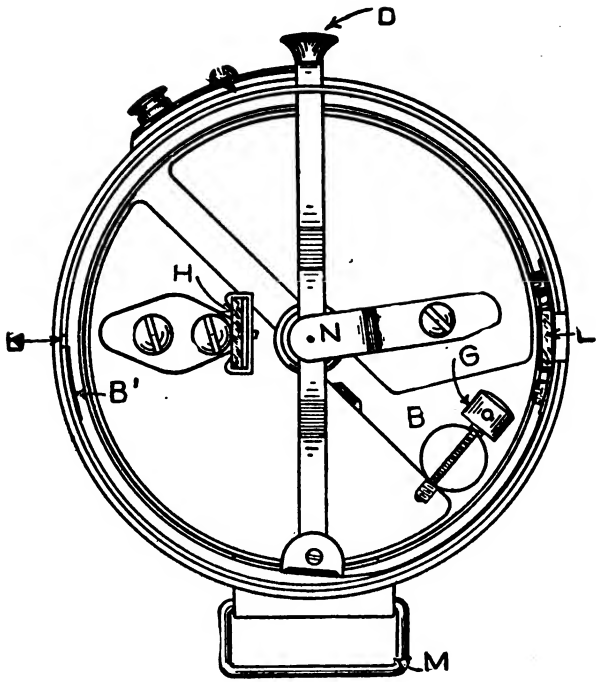

FIG. 41

$$\frac{3+2}{2} = \frac{5}{2} = -2\tfrac{1}{2} \text{ degrees.}$$

The clinometer gives minus readings too large and plus readings too small by ½ degree. This error may be corrected by screwing G to change the center of gravity of the pendulum; or every minus reading must be decreased and every plus reading increased ½ degree. Before starting each day's work, the correction to be made should be written on a corner of the drawing sheet thus: *Decrease minus (down) readings by ½ degree; increase plus (up) readings by ½ degree.* In using this

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clinometer, its flat sides should be held exactly vertical, preferably against some fixed object; and, *on completing the readings at any station, the sliding bar should be forced under the stop D to lock the pendulum.* This clinometer is one of the best types of hand instruments available for measuring slopes, but must be handled with care to prevent its being thrown out of adjustment. Its adjustment should be tested before each day's work.

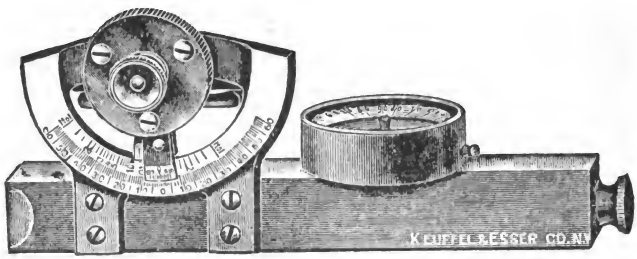

FIG. 42

(b) *The Abney Clinometer,* figure 42, consists of a sight tube, with a graduated arc and a level tube with index arm attached. Under the center of the level tube is an opening in the sight tube just above a mirror, in which the image of the bubble is seen by the observer as he sights the object. The bubble is placed in the center of its tube by turning the index arm until the bubble appears to be bisected by the horizontal wire across the end of the sighting tube. The reading of the index on the arc, when the bubble is at the center, is the slope of the axis of the tube with the horizontal. The bubble should be in the center of its tube when the reading of the index is zero and the tube level.

To test this, lay the clinometer on a smooth topped nearly level post. Draw lines around the four edges of the sighting tube, and read the slopes of this position of the tube. Reverse the clinometer within these marks end for end and read the slope. These two readings should be equal in amount, one plus the other minus. If they are different, add the two readings, divide the

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sum by 2, and set the vernier at the result on the same side of the zero as the last reading. By means of adjusting screws bring bubble to center of tube.

84. The Aneroid Barometer, figure 43, has a scale of elevations in feet and a scale of heights of a mercury column in inches on its face. The scale of feet is adjustable so that it may be set at the elevation of any known point. The aneroid barometer measures the pressure of the air, and since this pressure is usually changing, the elevation of any point would not be read the same on the scale at different times. This change, due to changing air pressure, is not over 20 feet per hour in fairly settled weather. If, therefore, the sketcher sets the scale of feet at the known, or previously found, elevation of a station *immediately before moving to another,* the error in the determined elevation of the second station would be that due to the change of air pressure in the few minutes required to go this distance, probably less than 5 or 10 feet. This constant resetting of the scale may be avoided by reading the barometer just before starting and immediately on stopping, to get the *difference* of the two elevations. The barometer should only be used thus in finding the successive differences of elevations from station to station. The results obtained with the barometer as above described are sufficiently accurate for military sketches because of the very gradual distribution of the error over the entire sketch. There are conditions of air, however, in which the barometer readings are changing too rapidly for use, and therefore the sketcher must be able to proceed with the sketch, using other methods for determining elevations.

The barometer should be carried in an inner pocket to keep it at as uniform temperature as possible. The readings should always be taken with the barometer held in a uniform manner. The best method is to hold it vertical by its ring about 2 feet from the face during the reading. The face of the barometer

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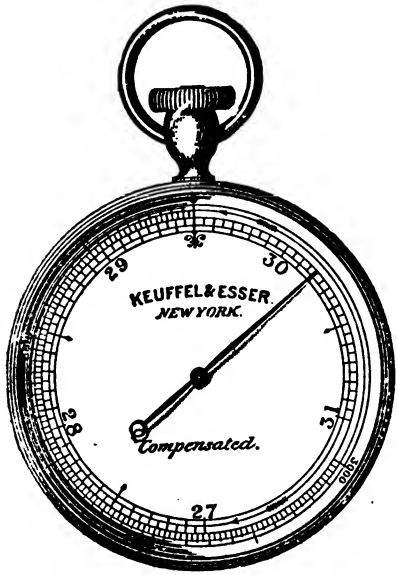

FIG. 43

should be lightly tapped two or three times with pencil or finger nail to prevent the pointer from sticking. The rate of change of the barometer should be tested every 15 minutes for about an hour before starting to work to find if the weather conditions are sufficiently uniform to admit of its use.

FIG. 44

85. *The Hand Level,* figure 44, has a sight tube similar to that of the Abney Clinometer. It has the great advantage that it practically can not get out of adjustment. It is a valuable sketching instrument for determining a horizontal line, and with

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degrees etched on the object glass vertical angles can be read rapidly and accurately.

86. *Horse's Walk and Trot as used in sketching.*—It has been found by several years' experience at the Service Schools that horses may be rated at the walk or trot so as to furnish measurements of distance with an error not greater than 5 per cent. This is sufficiently accurate for road sketches, except possibly on the main routes of a combined road sketch where carts are preferably used. The normal method of making road sketches is mounted, therefore, except for one or two preliminary sketches. The method of determining distance by the rate of the horse's walk and trot is more accurate than is possible by counting the horse's stride and sufficiently accurate for military road sketches, as the errors tend to compensate one another. Counting strides is also objectionable because the attention which must be devoted to it prevents that study of the ground so essential in road sketching. Unless the horse has a very steady walk and trot, it will not take a sufficiently uniform gait of its own accord. The sketcher must, therefore, carefully observe his horse's gaits and be able to *know if the horse is moving too fast or too slow.* For instance, a horse moves freer on starting out in the morning than later in the day when he is tired. His gait is slower going away from his barn than coming home, especially if it is near feeding time. A horse moves slower and more uniformly when alone on the road than when other horses are passing him. Two horses of equally uniform gaits trotting side by side move with greater uniformity than either one of them alone but if one of the pair is much more steady than the other, this one should be ridden in advance. The sketcher should learn the peculiarities of his horse and take necessary measures to keep him up to his proper gait when he lags and hold him in when he rushes ahead.

To determine a horse's rate, he should be ridden over accurately measured courses until the time required on any of the tests for

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the distance does not differ from the average by more than 5 per cent. This should be done for the walk and for the trot. In these tests, the sketcher should observe carefully the gaits until he is able to know when the horse is going at the proper rate and cause a change of gait when necessary. If the sketcher is to have an assistant in sketching, the two horses should be tested together and in the manner in which they will later be used. For instance, if the assistant is to ride beside the sketcher, the horses should be rated thus. If the assistant's horse is to keep the gait going in front, they should move in this order in the test.

It is sometimes found of assistance in keeping a uniform gait for the sketcher to rise to the trot because this enables a good estimate to be made as to the uniformity of time of the strides. Care must be used not to rate the horse faster than he can travel for a day's work. Most of the time in mounted sketching is spent at the halt, so rapidity of gait is not of much advantage. A slower gait gives better opportunity to the sketcher to study the ground forms and details. The trot is the habitual gait in mounted sketching and should be always used except on steep slopes. No correction need be made for grades, even in hilly country, because they do not appreciably affect the horse's rate; but the rating should be done over ground of the same nature as that to be sketched. Where the grade is steep enough to make any allowance, it is necessary to take up a walk to protect the horse from being staved up in the shoulders; and therefore, an accurate determination of the rate of the walk up and down steep hills is very important and should be done under these conditions. As soon as the sketcher is positive of the horse's gait, he constructs scales of minutes, halves, and quarters, see problem 3, par. 15. The scales should be tested in actual sketching, as described for the stride, because this work often causes a modification of the gait.

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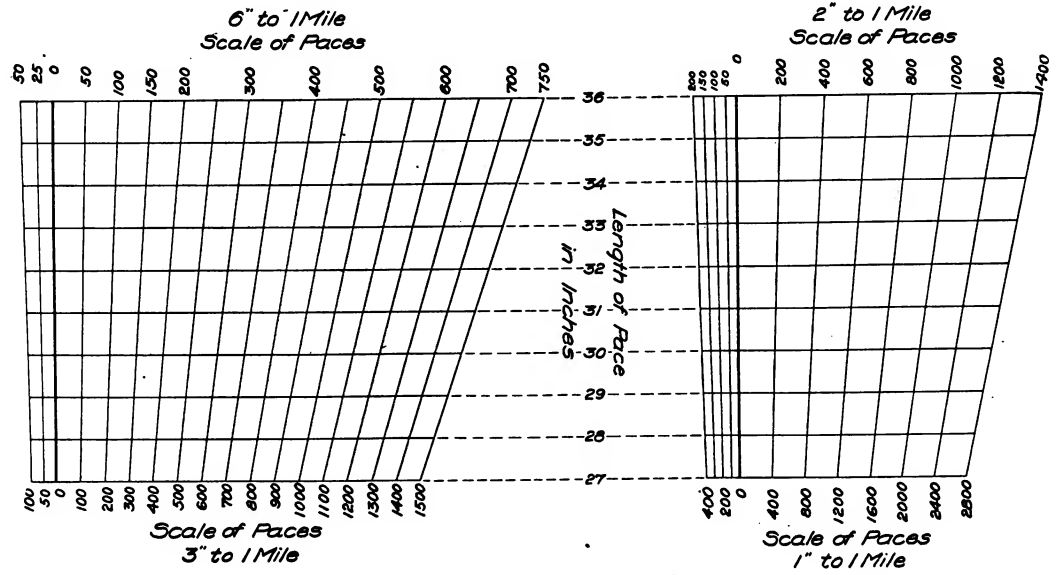

FIG. 45

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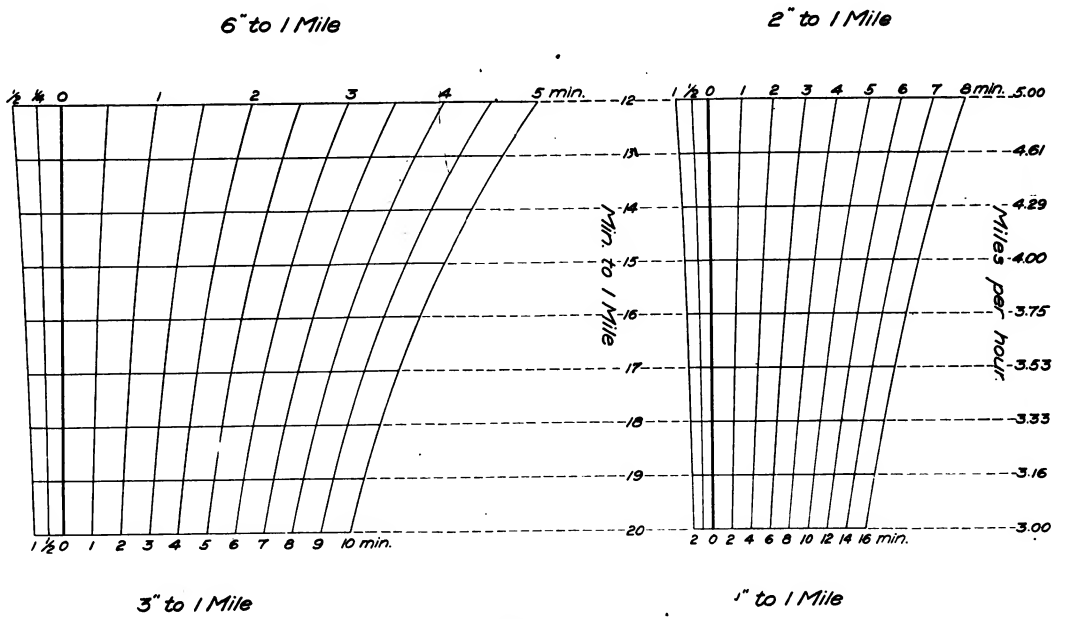

FIG. 46

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Rules for correcting scales: A sketch smaller than intended (scale too small) is caused by having assumed the horse's gait to be slower or the stride shorter than they actually are.

Should it be required to *make a mounted sketch on an unrated horse* when no time is available for rating, the sketcher should use the scale of average walk and trot; *a mile in sixteen minutes at a walk; and in eight minutes at a trot,* see figure 46. He should be able to keep the horse very close to these gaits, by his knowledge of gaits of other horses which he has ridden.

87. *The Distance Passed Over by a Revolution of a Wheel as used in road sketching.*—This method of determining distance is of great value in making road sketches, especially in combined work, because of the uniformity secured. The length covered per revolution is best determined by driving over a measured course and *dividing the length of the course by the number of revolutions.* This gives better results than measuring the circumference of the wheel, which slips and has side motions along the road. The rating course should be over average rolling ground to prevent measurements in the actual sketching from being too long on the hills where the wheel measures along the slope instead of the horizontal distance as it should. The number of revolutions is recorded by an *Odometer,* figure 47, attached to the axel of a front wheel and operated by a steel pin driven into the tend of the hub. This type is called the *Bell Odometer* and registers miles and fortieths of a mile (44 yards) and, as each mile is completed, a bell rings. This type is more accurate than the pendulum type usually furnished, figure 48, and is very convenient for sketching because the readings are easily visible from the seat of the wagon. With this odometer a scale of miles and fortieths would be constructed so that plottings would be directly from dial readings. Readings are continuous up to 1600 miles, and the most serious objection to this type is that there is no device for setting back to zero. A Veeder odometer reads tenths

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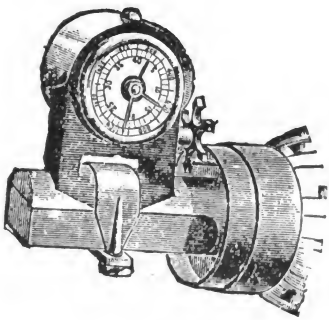

FIG. 47

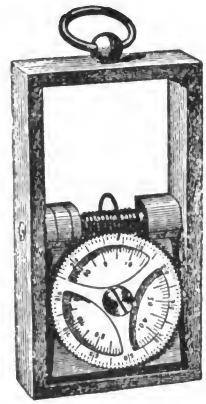

FIG. 48

of a mile, and may be set back to zero. The pendulum type is practically useless in sketching, because it must be removed from its case for each reading. In case no odometer is on hand, a piece of white cloth may be tied around the tire and the rotations of the wheel be recorded on a tally register by an assistant. If there is no measured course available over which to determine the length of one revolution, the circumference of the wheel is found by multiplying the diameter by 3.1416.

88. The *advantages of the Drawing Board* over other forms of sketching cases:

1. Its larger size gives sufficient area for two miles of position sketch in both directions; and about twelve miles of road sketch by running three traverses across the sheet. It is equally as portable as the Roller Sketching Cases.

2. Being practically square, the full length of the board is available, no matter what the direction of the traverse may be, without the necessity of orienting this board in some special position. The Cavalry Case and all similar ones have such a small drawing surface that it is necessary to orient the sketching case

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so that the traverse extends in the direction of the rollers. This direction of the road to be sketched will often not be known, thus causing the sketch to run off the paper frequently, with resulting delay and annoyance.

3. It has been found of great value in rapid sketching to have *flat sheets,* so that when the parts of the sketch are to be pasted together, the sheets will lie out flat without twisting and curling up, due to being on rollers.

4. *The attached ruler of the cavalry case* is a time consuming device, and should be removed and a *loose ruler* substituted. Simplicity of each article of equipment is absolutely essential to rapidity of work.

5. *The notebook and compass method has no advantage* over the drawing board method *except in very close country,* and is much slower, because the taking of intelligible notes from compass readings requires as much time as the making of a complete sketch with the board. The notes then require as much time to plot as was used in taking them. The errors mention in footnote to paragraph 82 are more liable to occur in this method and, in addition, other mistakes and omissions occur because the ground is not visible at the time of plotting. The reason often given for this method is that it can be used in the rain. The taking of notes in the rain is almost as difficult as sketching, and by use of *celluloid* with a ground surface, a pencil sketch can be made in the rain. This celluloid takes pencil lines readily even when it is perfectly wet. These lines may be readily erased with a soft rubber, but are not erased or smudged due to rubbing of hand and ruler in sketching. This celluloid is more transparent than tracing paper and allows blue prints to be made from the pencil sketches without retracing.

6. The Drawing Board equipment is easily improvised using a box top for the board and any straight stick for the ruler. The compass and tripod are not absolutely essential.

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